THE

GEOLOGICAL MAGAZINE

OR

Monthly Journal of Geology:

WITH WHICH IS INCORPORATED

"THE GEOLOGIST".

NOS. DLXXXIII TO DXCIV.

EDITED BY

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NEW SERIES. DECADE V. VOL. X.

JANUARY—DECEMBER, 1913.

LONDON:
DULAU & CO., LTD., 37 SOHO SQUARE, W.
1913.

STEPHEN AUSTIN AND SONS, LTD.

PRINTERS, HERTFORD.

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THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE V. VOL. X.

No. I.—JANUARY, 1913.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Dr. Eduard Suess,

Late Professor of Geology (1857–1908) in the University of Vienna; For. Memb. Roy. Soc. 1894; For. Corr. Geol. Soc. 1863; For. Memb. Geol. Soc. 1877; Wollaston Medallist, 1896; Copley Medallist, 1903.

(WITH A PORTRAIT, PLATE I.)

TO write an adequate notice of Professor Eduard Suess' work would be to review the progress of Geology during nearly half a century, for in all that time he was actively engaged in helping to explain the great problems connected with the formation of the features of the Earth's surface, and to trace accurately the principles upon which these have been brought about.

Born in London August 20, 1831, Eduard Suess went with his parents to Prague in 1834, his father being engaged as a merchant in the City of London in wool-importing from Bohemia, a business which had declined owing to the abundant arrival of wool from Australia.

Suess' first publication appeared in 1850, entitled a *Sketch of the Geology of Carlsbad and its Mineral Waters.*

In 1851 he was appointed an Assistant in the Imperial Museum, Vienna, and in 1857 to be a professor in the University of Vienna. In 1862 Suess resigned his museum work and devoted all his leisure not occupied by his lectures in the University to palæogeographical researches, which culminated in his great work *Die Antlitz der Erde*, "The Face of the Earth" (1883–5 and following years), wherein he endeavoured to show the main factors and methods which have ruled in geographical evolution. After a period of more than twenty years from its appearance in Vienna, an English translation of the first volume by Miss Hertha Sollas, edited by Professor Sollas, was issued by the Clarendon Press, Oxford, in 1904; whilst the fourth volume in its English dress was published in 1909, bringing the total number of pages up to 2,233.

"The first translation of Suess' great work, *Antlitz der Erde*, was into French (1897–1911), an edition which, thanks to the singular erudition of its editor, Mons. E. de Margerie, has been so enriched with footnotes as to become an invaluable work of reference for published papers in every department of the wide range of subjects of which it treats" (Geikie).

In a limited notice of Professor Suess' life-work, such as the present, it would be quite impossible to give an adequate idea of the

vast field of cosmical phenomena dealt with by him in his book. The dominant feature is the careful study of the earth-movements and foldings to which various districts have from time to time been subjected, some areas like Laurentia showing little or no disturbance since Cambrian times, the strata of that epoch lying horizontal, whereas other regions have been affected by more or less complex systems of foldings at successive epochs, the movements being influenced by buttresses of older rocks that have led to deflection and overthrusting.

But we must not overlook the various services rendered to science by Professor Suess during his long and brilliant career. By his lectures in the University of Vienna he exercised a powerful influence on the work of the distinguished school of geologists whom he taught —including such men as Neumayr, Mojsisovics, Fuchs, Waagen, Penck, and many others, which shows him to have been a great master of our science.

Since 1851 a steady stream of memoirs issued by him has proved him to be a great worker in geology, while the intellectual stimulus of his writings on foreign geologists shows him to be a great thinker.

Suess was never a specialist. He began work on Graptolites; he next laid the foundations of the modern classification of the Brachiopoda and Ammonites. Alpine problems roused his interest in dynamical and structural geology, and led to studies of the Austrian and Italian earthquakes, and to his suggestion of the connexion between these and the great circle of European Tertiary volcanoes and the elevation of the Alps. Work on the complex Tertiaries of the Vienna Basin and a study of the Mediterranean littoral geology led to his researches in Faunistic Palæontology, and so prepared the way for his pupil Neumayr. As a practical application of his geological studies in the Alps we may record that he greatly improved the water-supply of Vienna by bringing it from the Alps by an aqueduct 110 kilometres long.

For thirty years he was a Member of the Austrian Parliament, where he did good service for science. In 1863 Professor Suess visited London, for which city (as his birthplace) he had a strong attachment. In the same year he was elected a Foreign Correspondent of the Geological Society and a Foreign Member in 1877. He was made Copley Medallist by the Royal Society in 1903 and Wollaston Medallist by the Geological Society in 1896, and a Foreign Member of the Royal Society in 1904.

Professor Suess retired from the Chair of Geology after forty-four years active service, in his 77th year. In commemorating his 80th birthday on August 20, 1911, his friend Professor Steinmann delivered a eulogium on Professor Suess' work. He writes:—

"Far beyond his University, indeed wherever the sound of the German tongue reaches, the name of Eduard Suess will to-day be remembered with the profoundest esteem by every geologist and geographer, nay, almost by every naturalist as well . . .

"Scarcely any other investigator of modern times has influenced science so lastingly and deeply as Suess. For nearly half a century he devoted his mind to the great problem of the formation of the

earth's surface and in tracing accurately the principles upon which it was founded. Relying largely upon his ample observations and experience in former years, his work *Antlitz der Erde*, from 'the Origin of the Alps' in 1875 up to its conclusion in 1910, is a unique memorial of scientific, synthetic reasoning. In a masterly way he gathered up his facts from innumerable articles, extracting what was of value even to the smallest paragraph, whether geological or palæontological. For, to his mind, every stone might contribute to the construction of that monumental edifice which he was erecting with such careful hands . . .

"To the congratulations of the Viennese Geological Society offered to him on the completion of the final volume of the *Antlitz* he replied, 'the merit of the chief part of the work belongs essentially to those workers who have sacrificed their vital powers to carry out those investigations which I have recorded.' His activity as a University Professor not only benefited his class, but quickly spread beyond the walls of the lecture-room to all who would lend a willing ear to the progress of that science which he so zealously taught. To-day Suess completes the 80th year of his life. How few scientific men are permitted to retire from active work in their full health and vigour and in the enjoyment of all their faculties. He can look back upon a happy life as an investigator and a teacher; as an active citizen of Vienna, as president for many years of one of the most eminent Academies, and as an elected Member of Parliament. The son, who is on the point of taking his father's place at the University, also gives promise of most excellent abilities." [1]

Of Professor Suess' publications the list would be too long to give, but one may mention, however, specially, the following :—

"Ueber *Terebratula diphya*": SB. k. Ak. Wiss. Wien, 1852. [His Brachiopod and Cephalopod work was continued in many papers until 1870.]
Ueber das Wesen und der Nutzen palaeontologischer Studien. Wien und Olmüz, 1857.
Der Boden der Stadt Wien . . . Wien, 1862.
Die Entstehung der Alpen. Wien, 1875.
Das Antlitz der Erde. Prag, Wien, und Leipzig, 1883–1909; in French, Paris, 1897–1911; in English, Oxford, 1904–9.

II.—On upright *Equisetites* Stems in the Oolitic Sandstone in Yorkshire.

By Dr. T. G. Halle, of Stockholm.[2]

(PLATE II.)

STEMS of *Equisetites columnaris* (Brong.) have long been known to occur in a vertical position in the sandstones of the Inferior Oolite on the Yorkshire coast. This mode of occurrence has commonly been held as proving that the stems are preserved in the position in which they once grew, having been buried in situ beneath the layers

[1] *Die Geologie an der Wiener Universität in den letzten 50 Jahren*. Ein Blatt des Glückwunsches und des Gedächtnisses von G. Steinmann. Aus Geologische Rundschau, ii, pp. 368–9, Leipzig, Wilhelm Engelmann, 1911, 8vo.

[2] Communicated by Professor A. G. Nathorst, LL.D., Sc.D., Ph.D., Keeper of the Department of Fossil Plants, Royal Natural History Museum, Stockholm.

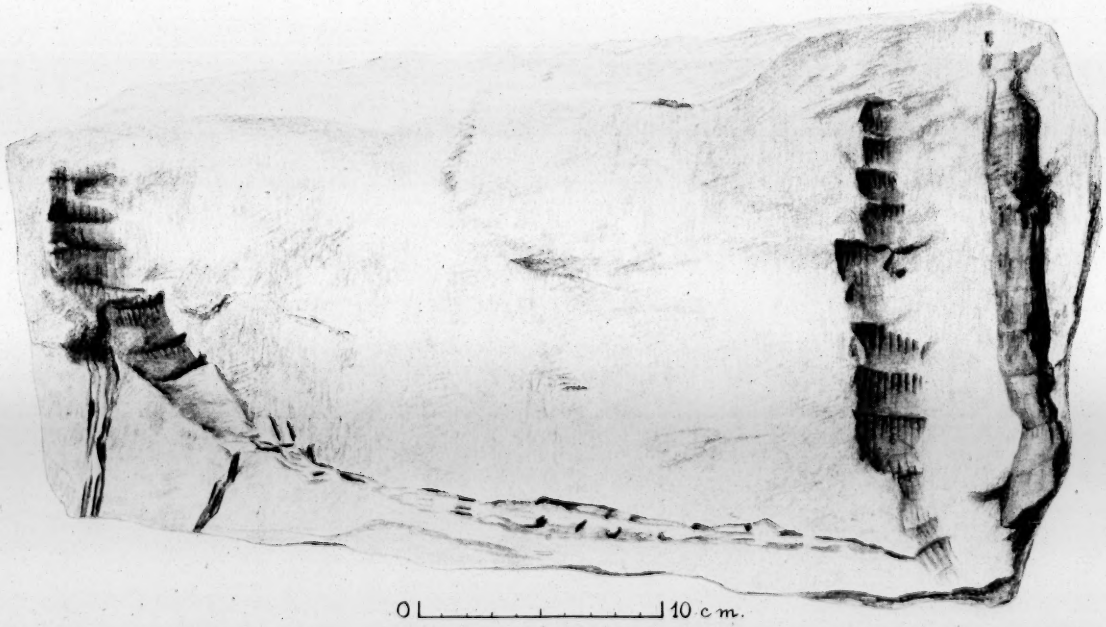
of sand that accumulated on the spot. On the other hand, it has been argued that the upright position need not be primary; it might be as readily explained if the stems are regarded as drifted and secondarily deposited on the spots where they are now found. It is well known and has been pointed out, particularly in the discussions of the upright stems in the Coal-measures, that a drifting tree often has a tendency to sink in a vertical position, the root-end being heavier because of adhering mineral matter or from some other reason. Phillips describes, in his *Geology of the Yorkshire Coast*, a locality at High Whitby where upright stems of *Equisetites columnaris* occur in the sandstone. He continues[1]: "They . . . are broken off or imperfect above, and seldom reach to the upper surface of the bed; they are also broken off below, but commonly pass to the lower surface; and some of the lower joints nearest the roots are found in the subjacent bed of shale." These facts have led, according to Phillips, to the conjecture that the plants grew in the shale "and were buried by an influx of sand and water". The other possibility, that the stems had been floating and deposited in vertical position, was at one time contemplated by Phillips, but he finally became convinced that "in several cases on the coast . . . *Equiseta* were prostrated and buried in abundance near to the spots where they formerly grew, and that here and there a few stems appear erect in the attitude of their marshy growth".

It would appear as if the idea of a preservation in situ of the upright *Equisetites* stems had been, in later years, discarded for the opposite one. Seward, who figures in his *Fossil Plants* a fine example of three upright stems in one piece of sandstone, expresses himself in the same work decidedly for the drift hypothesis.[2] The question does not appear to have received much attention lately, but it certainly deserves to be more studied both from a palæobotanical point of view and yet more because of its bearing on the mode of deposition of the sandstone. Many instances of occurrence of upright *Equisetites* stems have been noted by different geologists. It is not intended to give any review of the previous observations here; but the subject will be more fully treated by Professor P. Kendall in a paper following the present.

During a visit to the Yorkshire coast, in the summer 1910, for the purpose of collecting fossil plants, I paid, on the initiative of Professor A. G. Nathorst, some attention to the upright stems of *Equisetites columnaris*. The species is a very common one, and occurs in both the shales and the sandstones of the Lower and Middle Estuarine Series. In the shales the plant is mostly found as impressions or as very flattened casts lying on the bedding-planes. In the sandstones, on the other hand, it commonly occurs as upright cylindrical casts covered with a thin dark coating which often exhibits the teeth and other features of the leaf-sheaths. The vertical stems appear to be especially common in the sandstone cliffs of the Lower Estuarine Series along the coast from Whitby to Hayburn Wyke, but they are found also in

[1] J. Phillips, *Illustrations to the Geology of Yorkshire*, pt. i, The Yorkshire Coast, 3rd ed., p. 143, London, 1875.

[2] A. C. Seward, *Fossil Plants*, vol. i, p. 72, 1897.



Stems of *Equisetites columnaris* (Brong.) showing rhizomes. Lower Estuarine Sandstone, Inferior Oolite: Peak Alum Works, Yorkshire coast.

the Middle Estuarine Series, as for instance between Hayburn Wyke and Cloughton Wyke and at Scarborough.

The very abundance of the upright stems is perhaps rather in favour of the in situ hypothesis. This mode of occurrence is not only frequent but appears, in many places at least, to be the rule in the sandstone. The casts are often quite crowded and convey in a striking manner the impression of a fossil *Röhricht*.[1] A direct proof would be established, however, if rhizomes or roots of the plant were found to occur in connexion with the stems in such a manner that they must have grown into the sand. The stems are often seen to attain a considerable height in the rock, a couple of feet or more, and it is no doubt largely due only to the fact that the vertical surface of the sandstone cliffs generally does not quite coincide with the plane of the stems that these cannot be traced further. In some cases, however, the stems are found, when followed downwards, to disappear rather abruptly into an intercalated shaly layer, and it is then possible, as suggested by Phillips (l.c.), that their rhizomes have grown in that layer though they are usually not preserved. It is difficult, however, to establish a direct proof that such was the case.

Towards the end of my stay in Yorkshire, Professor P. Kendall, of Leeds, kindly conducted me to a place where he had discovered upright *Equisetites* stems occurring abundantly in the sandstone. The locality is at the Peak Alum Works close by the railway line between Robin Hood's Bay and Hayburn Wyke.[2] After a short search a few examples were found which appear to throw some light on the question. The best specimen, which is shown here in Plate II, was in a continuous wall of the cliff, but was broken out and is now in the collections of the Palæobotanical Museum at Stockholm. To the right are seen remains of two upright stems about 20 cm. high and with a diameter of 2–3 cm. From the lower end of one of these stems arises a lateral shoot or rhizome which continues for some distance almost horizontally at a right angle to the mother-stem, the horizontal portion being completely flattened and therefore looking very thin as seen from the side. About 25 cm. from the mother stem, this horizontal shoot begins to bend gradually upwards and continues in another upright stem. At the bend there arise from the shoot some sort of appendages, three in number, which cannot be anything but roots. These run in a downward course, and the two longest can be traced for a length of 7 cm. to the base of the piece of rock. The whole specimen is such that it cannot be satisfactorily accounted for except on the supposition that it is preserved in the position of growth. A branch has grown for some distance as a creeping rhizome and has then bent upwards to form another aerial stem. The roots arising at the bend must be taken to have grown into the sand, and it is probable that the sand had been accumulating all the time round the growing plant. I think this explanation must be admitted to be the more plausible one. To account for this complex specimen as drifted and later deposited would require the assumption of such improbabilities as might well be said to approach the impossible.

[1] Reed-bed.

[2] The stratigraphical conditions will be described in Professor Kendall's paper.

Another specimen is shown, on a larger scale, in Text-fig. 1. In this case there is a cylindrical cast which is not quite vertical but somewhat obliquely ascending. The cast is fairly thick, about 3·5 cm. in diameter, but only three internodes are preserved, with a length of about 10 cm. together. To two of the nodes, the one at the base and the second node above it, are attached horizontal branches, one to each node. The lower branch is very indistinct, being seen, in its flattened condition, only from the side. The upper branch lies on the upper surface of the piece of rock and can be seen from above. Its flattened cast has a breadth of 3–4 cm., and it can be traced for a distance of more than 16 cm. from the main stem to the edge of a piece of rock. Near the point of insertion of the branch there is seen what must be taken to be a root protruding obliquely downwards into the rock. Another root-like fragment is seen a little below a node near the middle of the horizontal portion. The main

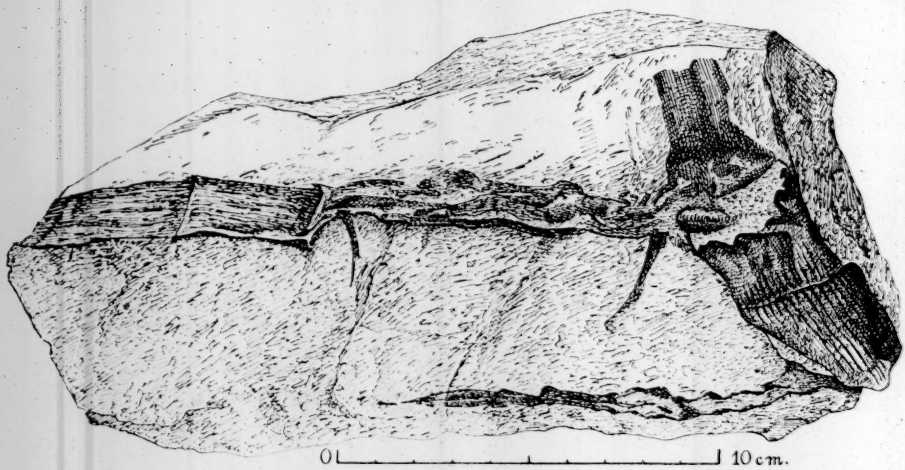


FIG. 1. Stems with rhizomes attached of *Equisetites columnaris* (Brong.). Lower Estuarine Sandstone, Inferior Oolite: Peak Alum Works, Yorkshire coast.

interest of this specimen is in the occurrence of creeping rhizomes at different levels above each other arising from the same stem. On the lower surface of the same piece of rock there is another horizontal, flattened cast, not shown in the Figure, which is no doubt a branch from the same stem, too, though the actual connexion is not seen. The horizontal portion has a length of about 20 cm.; then the branch bends upwards to form a new aërial stem, in the same manner as in the specimen figured in Plate II.

The features here described seem to indicate not only that the plants grew on the spot just as they are now found, but also that the accumulation of the sandstone proceeded while the plants were still growing. The sending out of creeping, root-bearing rhizomes from the upright stems at successively higher levels may be regarded as an

attempt of the plant to hold its own against the overwhelming sand. Similar cases of preservation are known from the Carboniferous formation, and have generally been regarded as proofs of an occurrence in situ and as resulting from the even balance between the growth of the plant and the silting up of its habitat. Some figures of Coal-measure plants given by Grand'Eury illustrate practically the same conditions, especially one showing a very fine group of *Calamites Suckowii* from the Carboniferous of Central France; and Grand'Eury's interpretation of the structure of this specimen is similar to the one applied here to the Yorkshire *Equisetites*.

If this interpretation of the vertical *Equisetites* stems is right, it will be seen to throw some light on the conditions under which the surrounding sandstone was laid down. On the spots where the *Equisetites* stems grew during the accumulation of the sand, the water must have been comparatively shallow, as the tops of the stems, at least, reached above the surface. The vertical casts cannot, as a rule, be followed for more than a few feet, yet it appears highly probable that the same conditions of sedimentation prevailed during the accumulation of thick banks of sandstone. The two specimens figured here come from beds at different levels in one and the same section of the sandstone, and it may be concluded with some probability that the intermediate beds were formed in the same manner too. There is no reason to regard the cases here described as mere exceptions. I am inclined to believe, both from the descriptions of the older writers and from my own observations, that the upright stems of *Equisetites* which are so common in the sandstones as a rule have been preserved under similar conditions, in which case the sandstone too should have been deposited in a uniform manner. It would be natural to imagine that the *Equisetites* grew in large, shallow fresh- or brack-water lagoons or protected estuaries with low marshy shores, and that these lagoons or estuaries were gradually becoming filled up by accumulating sand, the area being, during this process, slowly subsiding. The whole question, however, requires much more extensive observations, and it certainly deserves to be made the subject of special studies.

III.—Notes on the Stratigraphical Position of Beds with *Equisetum*.

By Professor Percy Fry Kendall, M.Sc., F.G.S.

DR. NATHORST mentioned to me in 1910 the fact that the rhizomes of *Equisetum columnaris* had not been observed, and I offered to show him a place where I thought they would be found. He had not time to visit the section on that occasion, but in the following year Dr. T. G. Halle accompanied me to the exposure and agreeably to expectation the rhizomes were found within a few minutes of our arrival.

The section is exposed at the Peak Alum Works (now Brick-works), where a splendid sequence is exhibited, extending from the Alum

[1] C. Grand'Eury, *Flore Carbonifère du Département de la Loire et du centre de la France*, Paris, 1877, p. 15, pl. i, fig. 1.

Shales (*Dactylioceras commune* zone) of the Upper Lias to the overlying Dogger Sandstone and Lower Estuarine Shales and Sandstones.

The succession is as follows:—

		ft.	in.
Lower Estuarine Series (71 ft. 2 in.).	Soil and rubble	4	0
	Sandstone	4	0
	Shale	4	0
	Sandy shale with boxstone concretions	5	0
	Splintered sandstone	6	0
	Raggy sandstone	3	6
	Grey and black carbonaceous shale	13	0
	Raggy sandstone with many rootlets in the upper part and erect stems of *Equisetum* in the lower 3 feet	4	6
	Sandy fissile shale with rhizomes of *Equisetum* and poorly preserved fronds of *Williamsonia*	1	0
	Grey shale without marked bedding, much resembling a Coal-measure 'seat-earth'	4	0
	Shale	7	0
	Nodular and ferruginous shale	3	0
	Coarse, massive, ferruginous sandstone	2	4
	Massive sandstone pierced with many vertical roots	2	3
	Compact sandstone	0	7
	Fissile sandy shale	1	0
	Black shale	6	0
	Dogger, very ferruginous columnar sandstone with pebbly base	3	0
	Upper Lias		

The Dogger Sandstone is unfossiliferous in this section, but its lithological characters are unmistakable. The columnar jointing is in many places extremely close and well-marked, the polygonal columns in some examples being not more than two or three inches in diameter. The pebbles at the base appear to be rounded concretions, probably derived from the Upper Lias. Some show small spheroids that may be of an oolitic character and remind me of the more sparsely oolitic varieties of the Cleveland Ironstone, to which I may have mistakenly ascribed pebbles in the Dogger at Wain-Stones (see Mr. Rastall's paper on the Dogger, Q.J.G.S., vol. lxi, 1905).

It is interesting to note that this section is the exposure of Dogger nearest to the Peak Fault that brings in a greatly expanded development of this division of the Lower Oolites, as well as Blea Wyke Beds and the *Striatulus* shales of the Upper Lias, no representative of which are found on the upthrow side of the fault.

The Lower Estuarine Beds present a strong resemblance to a section of Coal-measures, and were no doubt deposited under analogous condition; the chief difference between them is in the less degree of induration of the newer series. The *Equisetum* bed is easily recognized from the level of the railway (Scarborough and Whitby line) that passes through the quarry as the second bed of sandstone above the Dogger. Sandstone casts of *Equisetum* stems in the erect position pierce the sandstone in large numbers; some fallen blocks show transverse sections on the bedding-planes every 8 or 10 inches. Stems may be traced to a length of 18 inches. The top

ends are commonly twisted as though they had been wrenched round and bent over. A careful search in the overlying shale has so far failed to discover the much-desired fruits of the *Equisetum*, but I do not despair of finding them either here or at Blea Wyke. An exactly similar bed may be observed at about the same height above the Dogger beside the footpath descending the cliff in the re-entrant angle at Blea Wyke. The erect stems are contained in a strong bed of sandstone, and the flattened rhizomes occur in an underlying black shale in which many well-preserved fronds of *Williamsonia* occur.

I am indebted to my friend Mr. J. T. Sewell, J.P., of Whitby, for the following note, which shows that this is not the first record of the occurrence of rhizomes of this *Equisetum*:[1] "In one part of these cliffs was pointed out a place where a bed of sandstone, high up in the cliff, contains stems of reeds (correctly speaking these plants appear to be allied to the Equisetaceæ). These are an inch or more in diameter and 2 or 3 feet long, standing upright in the sandstone, while the shales below contain the traces of their roots." I suspect that the place alluded to is near the "Jackass Road" at Hawsker, whence the late Stephen Palmer used to obtain for me what he styled "pieces of cain" (cane).

IV.—The Physical History of the Norwegian Fjords.

By Professor Edward Hull, LL.D., F.R.S., F.R.G.S.

The Scandinavian Promontory.—This remarkable promontory, extending for over a thousand miles from the Naze to the North Cape, is formed mainly of Archæan rocks, consisting of gneiss, crystalline schists, and other metamorphic rocks, penetrated by granite and other igneous dykes of later date. These primeval rocks are overlain throughout a portion of their extent by Cambrian and Lower Palæozoic (or Lower Silurian) beds, between which and the Archæan masses there is entire discordancy, and, as regards their respective ages, a long period of unrepresented time. The Palæozoic beds are themselves highly altered when in contact with the intrusive igneous masses, so that it is difficult to distinguish them from the more ancient masses in some districts.

The older rocks are azoic, the later are fossiliferous.

These combined masses constitute a truncated ridge or plateau of rocks all rising into their highest elevations[2] towards the Atlantic coast and breaking off abruptly in stupendous cliffs traversed by deep and narrow channels, down which streams rising in the central snowfields pour their waters into the Atlantic; while in the other direction the general surface slopes down with a more gentle declivity towards the shores of the Gulf of Bothnia and the Baltic Sea. In consequence of this conformation of the surface the river

[1] Report by Sir Charles Strickland, Bart., of an Excursion by Tug-boat from Whitby to Peak of members of the Brit. Assoc. (York Meeting): Report of the Whitby Lit. and Phil. Soc., October 28, 1881.

[2] Snehætta reaches 7,615 and Galdhöpiggen 8,399 feet.

channels are less deep and precipitous on the eastern or Swedish side than on the western or Norwegian side of the peninsula, and the watershed approaches the western coast and is nearly conterminous with the boundary between Sweden and Norway.

The special interest regarding the Norwegian fjords is concentrated on those entering the Atlantic, and is not repeated in any other part of Europe. It is here, and nowhere else, that the waters of the ocean find their way up into the very heart of the mountains, the summits of which are covered by perennial snow giving rise to the streams which enter the fjords at their upper limits; and it is in Norway, and nowhere else, that the glacial ice falls directly into the waters of the Atlantic, as is the case with the Jökel Fjord, where detached masses of ice float away on the ocean surface. It is in Norway also that we find the largest snowfield of Europe, in the Jostedalsbræ, which is estimated to have an area of 580 square miles.[1]

From what has been said it will be evident that the fjords are continuous with the rivers draining the interior snowfields and glaciers, and are to be considered as partially submerged river valleys, or, as designated by Lord Avebury, "drowned river valleys."[2]

We have now to consider the process which has eventuated in the formation of these unique physical features.

The Archæan ridge in all probability formed part of a great primordial land barrier ranging along the Arctic Ocean in pre-Silurian times; but it is impossible to suppose that any of the streams now entering the Atlantic from Scandinavia had their origin at this period. However this may be, there can be no doubt that they drained a land surface from the Silurian period downwards throughout the whole of the vast lapse of time represented by the Mesozoic and Tertiary formations. These formations have no representatives in Scandinavia; and in their absence we may assume they were not deposited upon the submerged surface of the older formations. It is far more probable that the peninsula remained as unsubmerged land throughout the succeeding geological periods; and throughout this vast lapse of time the rivers which drained into the ocean were eroding their channels. This at any rate is the view I find it necessary to take, as it helps us to understand how, amidst rocks of such hardness as those of Norway, channels of the depth we contemplate, both emergent and submerged, were eroded; and have thus produced the lofty cliffs which rise from the banks of the streams and excite our admiration and astonishment: such are those of the Romsdal, the Gudvangen, and the Stalheim, rising from 2,000 to 4,000 feet on either hand from the river banks.[3]

The Fjords.—We shall now turn our attention to some of the fjords which I have myself visited and which, with the aid of the soundings on the Admiralty Charts, excite surprise by the depths to which they

[1] *Encyc. Brit.*, 11th ed., vol. xiv.

[2] *The Scenery of England*, 1901, p. 101.

[3] Professor J. W. Spencer has remarked that many of the sharper peaks and precipitous cliffs owe their form to the peculiar climatic conditions of Norway—the frosts of winter and long days of summer.

descend below the surface of the ocean-water with which they are filled; they are those known as the Sogne, the Hardanger, the Volden, and the Nord.

The Sogne Fjord is by far the largest of the Scandinavian sea-locks entering the Atlantic, and drains a very extensive area of mountain land. By means of the isobathic lines contoured from the sounding on the charts, one gains almost at a glance the form of the channel in which the water lies. Entering from the outer ocean with a comparatively shallow depth, the floor is found to descend rapidly downwards till it reaches to almost 4,000 feet (665 fathoms) below the surface, a depth which it retains for a considerable distance, only becoming shallower as it approaches the upper limit of the submerged channel, where it receives the waters of the rivers descending from the interior snowfield. The maximum depth is seen to occur where the fjord is bounded on either hand by mountain masses of great extent and elevation. Similar phenomena characterize the other fjords I have named above, and need not be repeated. They all increase in depth inwards from their outlet amongst the islands which follow the coast from south to north throughout its greater extent. This form of channel evidently requires explanation, being altogether different from that of river valleys elsewhere, which necessarily, in flowing from their sources to their outlets, descend from higher to lower levels.

The following are the depths to which some of the fjords reach towards the centre of their range between their outlet and their source:—

	Fathoms.	Feet.
The Sogne (about)	665	4,000
,, Hardanger	425	2,550
,, Volden	383	2,298
,, Nord	300	1,800

Assuming then, as I have done, that the fjords are partly submerged valleys of rivers which originally entered the Atlantic or the Arctic Oceans, it is clear that they could only have been eroded when they were in the condition of land surfaces—as rivers never erode their channels under the waters of the ocean.

As soon as rivers enter the ocean their erosive action ceases, and the force of the streams is dissipated. We must therefore suppose in the case of the Norwegian Fjords an uprise of the whole area to an extent of several thousand feet above the present level (in reference to that of the ocean) at a time when rivers flowed down them, and as such they must have had ever-deepening channels throughout their course. This is quite in accordance with the form of the river valleys of Western Europe which entered the ocean in recent Tertiary times.[1]

The Glaciation of Norway.—In order to account for the peculiar form of the channels it is necessary to invoke the effects of glacial snow and ice under its two heads; first, the erosive action of the ice itself, which, carrying in its mass fragments of rock, or sand, and under the pressure of thousands of feet of ice, wears down the floor

[1] As I have shown in my recently published monograph, *On the Sub-oceanic Physiography of the North Atlantic Ocean* (E. Stanford), 1912.

of the valley as it moves seaward; or second, the power of the ice in piling up masses of moraine matters on reaching the chain of islands which follows the coast from Stavanger (lat. 59°) to the Trondhjem Fjord. This, I understand, is the more favoured explanation with the Scandinavian geologists.

It is almost unnecessary to state that during the Glacial Period the whole of Norway and Sweden was covered deep with snow and ice, except where lofty peaks thrust their heads above the vast ice-field of the interior.

Those who are unfamiliar with the results of glacial erosion either in past or recent times in Scandinavia, the Alps, or the British Isles, in wearing down the surfaces of the hardest rocks into hummocky forms called *roches moutonnées*, or covering the surfaces with grooves and striæ, and transporting blocks of rock to great distances from the central snowfields and scattering them over the plains, can little realize the extent to which the glaciers of this region covered the lands and invaded the ocean bed during 'the Great Ice Age' of post-Tertiary times. The Norwegian ice, during a period of great elevation, descending in both directions filled the fjords, also the North Sea and, to a varying distance, the Atlantic, and meeting the ice descending from the Scottish Highlands caused it to change its course, while both together swept round the coast of Scotland and entered the Atlantic, where it was broken up and dissolved by the warm waters of the Gulf Stream.[1] On the other hand, the ice descending over the plains of Sweden filled the Gulf of Bothnia and the Baltic, and invaded the plains of Russia and neighbouring countries. During a recent visit to the Baltic I was everywhere greatly impressed by the evidence of the former action of the great ice-flow in moulding the surface of the rocks, and transporting from distant sources blocks of granite or other rocks which lie on the surface or have been turned to use for walls and buildings.

It can scarcely be doubted that on the Atlantic side this ice must have eroded the surface and deepened the beds of the fjords; and this view is confirmed by the fact that (as in the case of the Sogne Fjord) the position of maximum depth of nearly 4,000 feet is just where the fjord is bounded on either hand by mountains of great extent and elevation, and where in consequence the ice would accumulate in greater mass and be most effective in eroding the bed of the glaciers.

I conclude, therefore, that the ice of the Glacial Period has been an agent in deepening the channels of the valleys, but to what extent it is impossible to say, as we are not certain to what extent the piling up by moraine matter in the passage through the chain of islands has decreased the depth of the channels. We may, however, conclude that both these agencies have combined to produce the remarkable conformation of these wonderful sea-locks which give to the fjords their special interest. They are, as far as I am aware, reproduced nowhere else.

[1] This remarkable movement of the ice was first recognized by Professor James Geikie, and is shown in plate vii of the Monograph of the British Isles above quoted.

The Post-Glacial Subsidence.—The phenomena above described occurred during a period of high elevation, and was succeeded by one of corresponding depression, accompanied by a return of milder conditions of temperature and gradual disappearance of the ice from the fjords and lower regions of Scandinavia. In my view it was these changes of level which were the direct cause of the Glacial Epoch.[1]

The evidences of depression of the land are apparent in many places throughout Norway in the presence of old sea-beaches, containing marine shells of existing species, at levels of several hundred feet above the sea-waters. According to Reusch and Hansen, these terraces occur at levels of about 200 metres (615 feet) in the Christiania and Trondhjem districts, in front of the lakes of the east country forming large plains; but are generally at lower levels, sloping distinctly from higher positions in the interior of the fjords to lower levels towards the outer coast.[2] The terraces are composed of reconstructed glacial matter consisting of sand, gravel, and boulders, and the marine shells found in the glacial clays show a transition from the cold Arctic, to that of a milder, climate of the present day. Considering that the waters of the sea must have penetrated much further inland than at the present day, and that the conditions of the glacial stage were only passing away, we may suppose that the glaciers in many places actually entered the fjords, and gave rise to icebergs, which floated into the ocean waters, and on melting scattered their contents of mud and stones over the ocean bed. In this way we may account for the spread of glacial detritus over the floor of the North Sea, filling up the submerged channels of the rivers; and owing to this it is that the river valleys are seldom traceable by means of the soundings at the present day on the Admiralty charts.

Epoch of Re-elevation.—We now come to the consideration of the final stage upon which the peninsula entered in order to give rise to the relations of land and water now represented with admirable correctness on our charts. Re-elevation of the land was necessary for this result, but to a far less extent than that we have previously had to deal with. It was a case of a few hundred feet against several thousand, resulting in adding large areas of land along the margin and islands bordering the continent. Sweden must have gained enormously by this elevatory process, and many islands arose where the waters previously prevailed.

It is not my intention to discuss the question how these movements of the crust were brought about; this is a geological problem which physicists will solve in various ways. All I have to say is that it was not due to volcanic action, but is to be explained in accordance

[1] This is the view which I have endeavoured to develop in my monograph above alluded to, and I hope successfully. Judging by the results obtained by the soundings, the submerged river-channels descended to over 1,000 fathoms (6,000 feet), which gives the amount of the uplift of the land above the present level of the ocean. But for full evidence of this conclusion the reader is referred to the monograph itself.

[2] According to Professor James Geikie, quoting from Erdman, the terraces are found at levels up to 800 feet or more above the surface of the sea. (*Great Ice Age*, p. 388.)

with terrestrial movements which have occurred from time to time throughout all geological history. But, in order to measure the movements, it has been necessary to recognize the level of the ocean as a datum for reference in accordance with the views of our great master Lyell. But I would only point out that however great the oscillations of the crust may appear to us living on its surface, they will appear extremely diminutive when measured by the length of the earth's radius, which is the true standard of measurement.

V.—North American and European Drift Deposits.

By R. M. Deeley, M.Inst.C.E., F.G.S.

(WITH A FOLDING TABLE.)

THE classification of the drift deposits is one which has given rise to very divergent views. One school holds that the Glacial Period was marked by increasingly severe conditions of climate followed by a somewhat regular amelioration. Another school holds that it consisted of a series of cold periods separated by warm intervals. It is not contended that in Pleistocene times the ice disappeared completely; for it is pretty certain that on high mountain ranges, and in the Arctic and Antarctic areas, snow-fields and glaciers existed continuously. With cold conditions the ice-covered regions spread from the Polar areas and glaciers descended from the mountains, and with the return of warmer conditions the Polar glaciers and ice-fields decreased in area whilst the mountain glaciers again retreated up the valleys. The problem as to the extent to which such variations in glacial conditions occurred, and the number of times they recurred, can only be settled by a study of the Pleistocene deposits themselves. In this matter theory cannot at present help us.

During recent years much work has been done which has an intimate bearing upon the question, and several geologists have given their views on the subject of the classification of the drifts. In North America, where drift deposits are especially well developed, our knowledge of them has been greatly increased by the work of Salisbury, Chamberlin, Calvin, Wiedman, Upham, Calhoun, Tarr, Gilbert, Coleman, Stone Alden, Leverett, and many others. In the European Alps and North-West Europe, Penck, Bruckner, Suess, Hess, Forel, Wahnschaffe, Keilack, French, Credner, Emil Werth, Klantzsch, Berg, and many others have done a great deal in the classification, description, and mapping.

In 1895 James Geikie [1] gave us a classification of the glacial deposits in which he attempted a correlation of the North American with the European deposits, whilst Frank Leverett [2] in 1910, in the light of more recent work, has again dealt with the question in some detail. His paper is printed in English.

Leverett spent the year 1908 in Western Europe in a study which had for its aim a comparison and tentative correlation of the glacial deposits in that area with those of the United States, on the study of

[1] *Journal of Geology*, vol. iii, pp. 241–69, 1895.
[2] *Zeitschrift für Gletscherkunde*, vol. iv, pp. 242–95, 321–42, 1909–10.

NORTH AMERICAN AND EUROPEAN DRIFT DEPOSITS (LEVERETT).

	North American.	British.	Alpine.	North-West Europe.	
	Three centres of ice dispersion: Labrador, Kewatin, and Cordilleran.	Ice dispersion from British Mountains and Scandinavia.	Dispersion from the Alps of France, Switzerland, Italy, and Austria.	Ice dispersion from Scandinavia.	
1	*Jerseyan Drift.* From Labrador; scattered patches deeply weathered. *Nebraskan Drift.* From Kewatin; is largely a compact blue-black boulder-clay with much woody material. *Allegany Drift.* Well developed: contains large boulders and much silt and fine sand. All these drifts much weathered.	? *The Chalky Clay* of the extreme south-east of England, near London, is much more weathered than the Contorted Drift and may be older than it. There seems little question that the Boulder-clay of this region is but a meagre remnant of a very old deposit of an age equal to, if not greater than, the Kansan Drift.	*Günz Drift* and older Deckenschotter. Almost completely covered by later glacial deposits, but its glacial outwash, known as the older Deckenschotter, is spread widely over the plains bordering the Alps. It is very much weathered and in places cemented into a conglomerate.	*Scanian* of North Germany. Boulder-clay and fluvio-glacial drift.	1
A	*Aftonian.* Beds of sand and silt with peat. Also soils and weathered zones. Mammals: horse, elephant, mastodon, *Megalonyx*, and *Mylodon*. Freshwater shells similar to those living in region to-day. Peat contains *Hypnum* mosses. Woody plants largely coniferous.	*Saxonian.* Forest Bed Series of Norfolk. (*a*) Complex series of marine and fluvio-marine or estuarine deposits which show, in passing up, a change from warm temperate to Arctic conditions. Contains glacial erratics. (*b*) Forest Bed. Plants still indigenous to Norfolk. Freshwater shells, fishes, amphibia, reptiles, and mammals of recent species. Extinct mammals of more southern type.	*Günz-mindel.* Long interval, indicated by the great amount of erosion of Günz outwash. Identification of interglacial deposits of this age difficult. Lignite beds of Liffe, which contain early forms of elephant and rhinoceros, may be of this age.	*Paludinenbank of Berlin.* Molluscs: *Paludina*, *Unio*, *Pisidium*, *Bythinia*, *Valvata*, and *Neritina*.	A
2	*Kansan Drift* from Labrador and Kewatin. Remnants of this drift occupy the divides, 70 to 90 per cent having been removed by erosion. The upper portion is much weathered to a depth of several metres, the weathered portion having been deprived of its limestone, while the granites are in an advanced state of decay.	*Contorted Drift.* The amount of weathering this has experienced is very similar to the Kansan Drift, and morainic features are as pronounced as those of Holland.	*Mindel Drift* and younger Deckenschotter outwash. It is the most extensive of the glacial formations along much of the northern border of the Alps. It connects with extensive deposits of glacial outwash, known as the younger Deckenschotter, which is found in broad valleys excavated through the older Deckenschotter.	*Lower Diluvium.* This old drift is exposed in a narrow strip outside the middle and young drifts, from the Russian boundary westward to the North Sea. Contains numerous Scandinavian erratics. Is much eroded, and where porous much weathered. Some dense non-porous clays are not much weathered. Morainic ridges are noticeable in the Netherlands.	2
B	*Yarmouth Soil and Loess* are deposits of peat, sand, and silt, containing woody material and bones of the wood-rabbit and skunk. The pre-Illinoian loess and silt deposits are of this age, and contain large numbers of land shells and some aquatic.		*Mindel–Riss.* The Höttinger Breccia, near Innsbruck, whose flora calls for a warmer climate than the present, is now referred by Penck to this age. The great length of this interglacial stage is shown by the large amount of erosion the Mindel Drift and outwash experienced before the Riss Drift was laid down.	*Rixdorf interglacial horizon* of North German plain. It contains an exceedingly rich fauna of large mammalia. In Central Russia there also occurs a series of interglacial deposits consisting of lacustrine marls below and loess above. The lower beds contain spruce, larch, willow, and other plants which do not live near ice-sheets. It is covered by and rests upon Boulder-clay.	B
3	*Illinoian Drift* from Labrador and Kewatin. The Illinoian drift of the Labrador ice-field is widely exposed outside the limits of later drift. It has not been so severely eroded as the Kansan Drift, and was originally very calcareous; but has been leached to a depth of about 6 feet.		*Riss Drift* and high terraces of Alpine region. It differs little from the third drift of the North German foreland. In the Riss Valley the ground moraine has a gently undulating surface scarcely to be distinguished from the surface of the glacial outwash. It is a coarse gravel, becoming in places cobbly and bouldery.	*Middle Drift* of North German lowland. It is fresh in aspect, and although loess-covered is now considered as of later age than the Lower Diluvium.	3
C	*Sangammon soil and main Loess* deposits of central States consist of soil, muck, and peat covered by loess. Contain *Elephas primigenius* in some of the clays and *Hypnum aduncum* in the peat. Loess was derived from the great plains east of the Rocky Mountains and spread by wind over the more eastern plains.		*Riss–Würm.* This interglacial stage was marked by somewhat extensive erosion and the collection of loess upon the Riss Drift. The majority of the interglacial deposits below the later or Würm Drift are referred by Penck and Bruckner to this stage, but some of them may really be older.	*The loess* is a wind-carried deposit, the principal mass of which seems to have been deposited during this interglacial stage. It contains terrestrial mollusca mainly.	C
4	*Wisconsin Drift* from Labrador and Kewatin. The Wisconsin Drift deposits have suffered very little denudation, and these new-looking drifts are regarded as of this age, whether covered by loess or not. A large number of distinct moraines were formed during temporary advances when the ice was melting away.	Boulder-clays, etc., east of the Pennine, and morainic deposits between Pennine Hills and North Wales.	*Würm Drift* and low terraces. The moraines which mark the limits of this glaciation are usually very strong ridges strewn with boulders of all classes, and showing but slight surface weathering. Recent glaciers of the Riesen Gebirge and Schwarzwald.	*Upper Diluvium.* There are broad belts of unweathered moraine of this age stretching across the entire breadth of the German Empire, called Grundmoranenlandschaft.	4

To illustrate Mr. R. M. Deeley's paper on Drift Deposits.

which he had been engaged since 1886. In this European study about three months were spent in making the circuit of the Alps. The several drift sheets were studied under a variety of topographic conditions. Several months study in the North German lowland extended from the Russian boundary westward to the Netherlands. The limits of the last glaciation and of the next older glaciation, as well as the characteristics of each of their drifts, compared with a still older drift, exposed in recesses of the mountains along the south side of the lowland, were leading subjects of study. In Great Britain the study consisted of a few trips only along the eastern coast and brief visits to the interior. This will account for the small notice taken of British Pleistocene deposits.

Leverett remarks: "It would be presumptuous for one to pretend to clear up the matter of worldwide correlations of glacial deposits in a single year's study; and no one perhaps realizes better than does the writer what a small start can be made in this brief time. A full correlation, however, may in time be reached by repeated efforts of this sort. Even though tentative it seems worth while at this time to state what impressions and results were obtained."

In Table I are given in outline the main results arrived at by Leverett. Nos. 1, 2, 3, and 4 are the four well-marked cold periods, whilst A, B, and C are the interglacial warmer periods. For fuller details the paper itself should be referred to. Attention may be called to the fact that both in North America and on the continent of Europe, the trend of glacial work is to support the view that there were at least four cold periods separated by long warm intervals. J. Geikie has shown that even after the Wisconsin–Würm period there were climatic oscillations, probably of short duration, which led to considerable increases and decreases in the size of valley glaciers. This view is also held by Swiss and German geologists of note.

Penck and Brückner[1] show that during each of the four cold periods when the glaciers debouched upon the foreland enormous quantities of gravel and sand were thrown out over the country, filling up and obliterating all traces of many valleys. These outwash gravels were formed when the mountain valleys were filled with great glaciers and were grinding and plucking the rocks upon which they rested. The fine rock flour found its way down the rivers to the sea.

During each interglacial stage, when the glaciers had almost wholly melted away, the rivers cut deep valleys through the outwash gravels. Thus valleys were eroded during warm periods and again filled by outwash gravels during cold periods. There is very good evidence that during the four main glacial periods the precipitation of moisture was about the same as that during the warm periods, and that the development of the glaciers was almost entirely due to fall of temperature.

We, therefore, see that during the glacial periods the rivers were so charged with debris that they could not transport it at normal gradients, and, as a result, they deposited pans of outwash material. With the disappearance of the great glaciers great erosion ceased, and

[1] *Die Alpen Ciszeitalter.*

DIAGRAM TO ILLUSTRATE GRAPHICALLY THE GLACIAL AND INTERGLACIAL PERIODS.
(After Penck and Bruckner.)

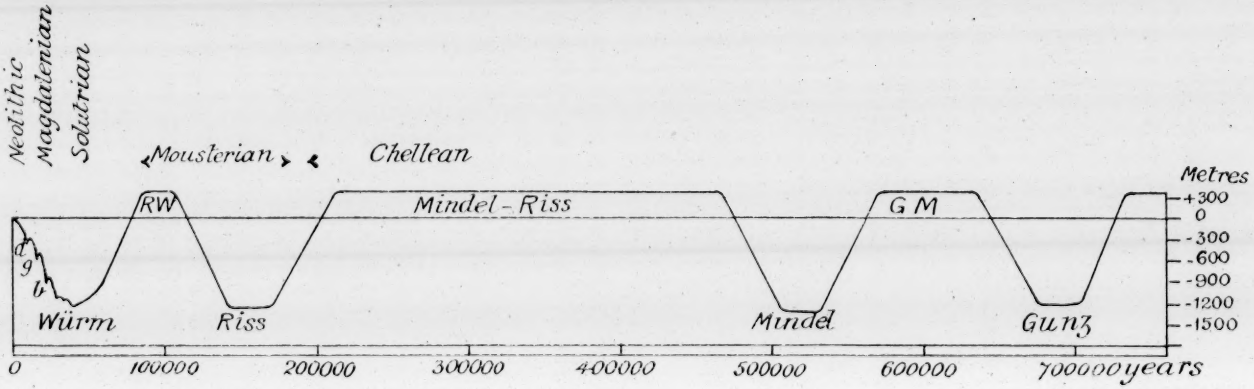


FIG. 1.

Glacial Periods: Würm, Riss, Mindel, and Gunz. Stages: *d* Daun, *g* Gschnitz, *b* Bühl.
Interglacial Periods: RW. = Riss–Würm, Mindel–Riss, GM. = Gunz–Mindel.
Culture stages of man: Neolithic, Magdalenian, Solutrian, Mousterian, and Chellean.
Ordinates show variations in height of snow-line. Abscissæ show estimated ages in years.

the rivers were again able to re-excavate valleys through the outwash deposits; terraces and plateaux of these gravels now overlook the river courses.

Penck [1] has given an excellent description of the erosive action of glaciers, showing how the recognized features of glaciated mountain regions have been produced.

Concerning the duration of the Glacial Period as a whole an interesting diagram is given by Penck & Bruckner,[2] the main features of which appear in Fig. 1. It must be remembered that many geologists have been induced to consider the Glacial Period of short duration because calculations based on the temperature gradient of the earth's crust appeared to show that the habitable age of the earth was between fifty and one hundred million years. But the discovery of radium and its heating effects have served to show that this view was based upon incomplete data. We may, therefore, give full weight to geological evidence when dealing with the age of deposits or periods. Penck & Bruckner do not contend that they have done more than make an estimate, and, although their estimate may be either too great or too small, it has been made with a very full knowledge of the Alpine phenomena.

The scale in metres at the end of diagram, Fig. 1, gives the height to which the snow-line was raised or lowered as a result of the changes of temperature, whilst the scale at the bottom shows the estimated age in years.

During the retreat of the ice of the Würm Period pauses and readvances took place. Three of these stages, the Daun (*d*), Gschnitz (*g*), and Bühl (*b*), shown on the diagram, have been clearly recognized in many localities. Above the diagram, the position of several of the stages which marked the advancing culture of man is shown.

A large number of moraines, showing halts or readvances of the Wisconsin ice-sheet in North America, have been mapped and described among others by Leverett.

VI.—Spilite Lavas and Radiolarian Rocks in New South Wales.

By W. Noël Benson, B.Sc., Emmanuel College, Cambridge.

THE very interesting remarks made by Messrs. Dewey and Flett on "Some British Pillow-lavas and the Rocks associated with them"[3] have further emphasized Dr. Teall's observation of the intimate association of Radiolarian rocks with lavas of this character, and which is particularly well developed in Europe in the later Devonian formations. It is further shown that such rocks are characteristic of areas of continuous off-shore subsidence, and are often intimately associated with intrusions of dolerite, quartz dolerite, gabbro, and serpentine.

Perhaps no occurrence of Radiolarian rocks is more often cited than

[1] *Journal of Geology*, vol. xii, pp. 1–19, 1905.
[2] *Die Alpen in Ciszeitalter*, vol. iii, p. 1168.
[3] Geol. Mag., 1911, pp. 202, 242.

that in the Tamworth District of New South Wales described by Professor David and Mr. Pittman, for these give clear evidence of their origin in comparatively shallow water.[1] The occurrence of spilitic rocks among these also has now been determined. Recently the writer has surveyed the greater portion of the Great Serpentine Belt of New South Wales, which extends from Bingara and Warialda, more than a hundred miles N.N.W. of Tamworth, to beyond Nundle, over thirty miles to the S.S.E. of the same town. A detailed description of this very interesting and diversified area is now in preparation. The following will here suffice to indicate the main points pertaining to the present subject.

The general sequence of the pre-Permo-Carboniferous formations observed is stated below. The series appears conformable throughout. The figures given are the apparent thicknesses only, and serve merely to indicate how great are the masses of sediment involved. Doubtless much repetition by faulting has occurred, particularly in the older formations, but at present it is impossible to estimate to what extent this is present. The sequence is as follows:—

Rocky Creek Conglomerates.—These are conglomerates and sandstones, interstratified flows of rhyolite and trachyte, and felspathic tuff beds. They contain *Ænimites orata* and *Lepidodendron veltheimianum*. Their age is considered Middle Carboniferous, and the thickness is certainly more than 2,000 feet.

Burindi Mudstones.—These are composed of evenly bedded mudstones and occasionally limestones containing a rich Lower Carboniferous marine fauna. The thickness is about 1,500 feet.

Barraba Mudstones.—These consist of mudstones and clay stones with frequent Radiolarian bands differing from the non-Radiolarian beds chiefly in their somewhat finer grain size. Frequently bands of andesitic or felsitic tuff are present, also lenticles of non-fossiliferous argillaceous limestone. *Lepidodendron australe* is abundant. Their age is probably Upper Devonian. Their thickness is very great, *apparently* exceeding 13,000 feet. They have a wide distribution, covering more than a thousand square miles.

Baldwin Agglomerates.—These are coarse agglomerates with rounded pebbles of most of the older rocks set in a tufaceous matrix of felspar and augite crystal fragments, chips of spilite, etc. Occasionally narrow, rapidly chilled, spilite flows are interstratified, and rarely bands of very fine-grained felspathic chert containing Radiolaria. These beds commence near Tamworth (Cleary's Hill agglomerates of the previous authors), increase in thickness to over 1,800 feet, and die out again near Bingara, about one hundred miles to the north. Their age is assumed to be Upper Middle Devonian.

The *Tamworth Series* comprises Radiolarian banded cherts and claystones, fine and medium-grained tuff, of a composition similar to the matrix of the Baldwin agglomerates, but with smaller grain size. A well-marked coral limestone occurs, with an abundant Middle Devonian fauna,[2] sometimes as a string of small lenticular masses, sometimes a broad band. Spilite flows are numerous. They

[1] Quart. Journ. Geol. Soc., 1899, pp. 16–37.

[2] R. Etheridge, jun., Records Geol. Survey N.S.W., vol. vi, p. 151.

are especially noteworthy at Bowling Alley Point, near Nundle. The apparent thickness is about 10,000 feet, of which the portion of the series developed at Tamworth forms a little more than the upper half. It is believed the thickness given previously for this portion should be reduced.

The *Woolomin Series* consists of red jaspers with Radiolaria, claystones, tuff, and spilites, all in a very altered state. Its extent is large and stratigraphy greatly disturbed. Age, Lower Devonian.

The general sequence of geological events is believed to be as follows:—

Deposition of Woolomin and Tamworth Series took place on a sinking coast, and was interstratified with numerous spilite flows and layers of tufaceous material. Increase in igneous activity in

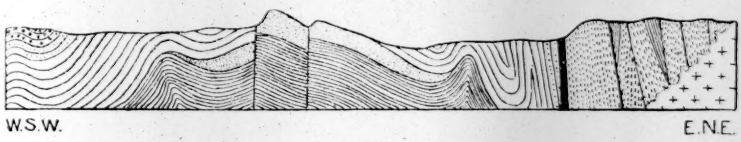


FIG. 1. Generalized Section, Northern Type, about 30 miles long.

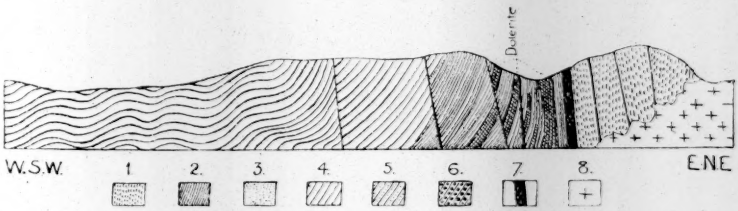


FIG. 2. Southern Type, about 20 miles long.

1. Woolomin Series.
2. Tamworth Series.
3. Baldwin Agglomerate.
4. Barraba Mudstone.
5. Burindi Mudstone.
6. Rocky Creek Conglomerate.
7. Serpentine.
8. Granite.

the central region brought about the deposition of the Baldwin agglomerates. In the south this activity was expressed by the intrusion into the Tamworth Series of great sills of dolerite and quartz dolerite often very coarse-grained. These are also known in the northern region, but have not yet been so fully studied. Except for occasional bands of tuff and fine breccia, igneous activity was slight in the Barraba times and temporarily ceased in the Burindi era. Orogenic movement commenced in Middle Carboniferous, and was expressed by the heavy conglomerates and the flows of acid lava. This movement (a thrusting directed from the E.N.E.) tilted the strata vertically and slightly overturned them. A great mass of peridotite was intruded into these upturned strata along a line of fault which runs throughout the length of the Radiolarian Series, and has been traced to fifty miles south of Nundle. A sill or dyke of serpentine thus runs intermittently for nearly two hundred miles. Pebbles of this serpentine occur among the Permo-Carboniferous

series in the Newcastle District to the south, and Jurassic sandstone lies horizontally on its denuded surface.

Following the peridotite intrusions (with which came a minor amount of eucrite-gabbro) were minor intrusions of dolerite followed by a sequence of granitic intrusions that extend into the early Mesozoic. (See Figure, p. 19.)

The spilite lavas are similar to those described by Messrs. Dewey and Flett. They are dense, fine-grained, often more or less vesicular. In texture they are trachytic or pilotaxitic, with a varying amount of augite and magnetite among the felspar laths. According to the character of the occurrence the rock will have well-formed or skeleton crystals of felspar and iron ores, less rarely is the pyroxene well-formed. A partly devitrified base may be present; more rarely the rock is holocrystalline. Usually the augite is entirely changed to uralite and other products, and the felspar indeterminable through clouding with sericite chlorite, epidote, etc. Where determinable the felspar is invariably albite-oligoclase. The following chemical analyses will serve to show the affinity with spilites of Cornwall. As will be seen, this similarity descends even into such a minor point as the absence of barium.

	I	II	III	IV
SiO_2	48·22	48·58	47·56	53·17
TiO_2	2·68	1·77	2·40	1·85
Al_2O_3	14·82	14·58	14·27	9·36
Fe_2O_3	·56	1·89	1·63	1·29
FeO	9·25	7·65	6·80	9·62
MnO	·23	·46	·30	·19
MgO	5·58	6·36	4·90	9·00
CaO	8·81	9·80	10·95	7·46
Na_2O	4·95	4·02	4·61	4·26
K_2O	·44	·43	·27	·48
H_2O+	2·54	2·93	2·65	1·80
H_2O-	·15	·68	·42	·07
CO_2	1·40	1·00	2·95	1·17
P_2O_5	·23	·19	·19	·12
FeS_2	·37	·26	·22	·30
BaO	n.f.	n.f.	n.f.	n.f.
SrO	tr.	—	—	—
Cr_2O_3	n.f.	—	—	n.f.
Ni Co O	0·3	·03	·08	·04
Fe_7S_8	—	—	·05	—
	100·26	100·63	100·25	100·18

I. Spilite, Nundle, New South Wales (analysed by W. N. Benson).
II. ,, Mullion Island, Cornwall (analysed by W. Pollard).
III. ,, Tregidden, Cornwall (analysed by E. G. Radley).
IV. Albite dolerite, Bingara, New South Wales (analysed by W. N. Benson).

The dolerites associated with the spilites are similar to those occurring with spilites in other localities. While in certain rocks, particularly those containing quartz, the plagioclase is andesine, in others it is nearly pure albite. They are often strongly titaniferous, and may contain a good deal of apatite and primary pyrites. The augites are more or less uralitized.

Another point of interest in connexion with these Australian

spilites may be mentioned. About a mile north of the point where the analysed specimen occurred spilite is found associated with coral limestone containing fragments of recognizable coral. The microscopical structure has every indication of rapid cooling.[1] This seems to show clearly that spilite lava has flooded over a living coral reef and is not therefore necessarily a deep-sea lava. Radiolarian beds occur above and below this curious association of lava and limestone.

The Sedgwick Museum, Cambridge.

VII.—The Upper Trias of Leicestershire.

By A. R. Horwood.[2]

Part I.

1. General Description of the District.
2. Summary of Previous Work.
3. Stratigraphy of the District.

Part II deals with Physiography, Tectonics, Petrography and Lithology, Palæontology, Economics and Water Supply, Sections, Bibliography, Appendix.

1. General Description of the District.

THE Upper Trias of Leicestershire as a whole occupies the western half of the county, being bounded on the east more or less by the Soar Valley, following the strike (as a subsequent in part of its course up to its junction with the Wreake). In fact, it is on the eastern boundary near the outcrop that the beds are mainly best exposed, the region to the west south of the coal-field around which it mantles being little developed and presenting fewer exposures.

The area under consideration is not less than 300 square miles in extent. It reaches from the River Trent, the northern boundary, to the Watling Street in the south, and from the eastern boundary, roughly coinciding with the Soar Valley and Midland Railway, to the western boundaries of the county, adjoining contiguous tracts of Trias in Warwickshire and Staffordshire. There are two main outcrops within this area of older rocks, the Carboniferous and Permian rocks, with Bunter in the north-west, between Moira and Ashby-de-la-Zouch, and the Charnian range of hills of Pre-Cambrian rocks 5 miles north-west of Leicester. Outlying outcrops of syenite between Hinckley and Leicester in the south, and of granite at Mountsorrel, Buddon Wood, etc., north-west of Leicester, also rise up as knolls in the Red Marl area. Elsewhere glacial deposits cover the Trias, especially south and east of Charnwood.

The Lower Keuper follows the Permian and Bunter outcrops on three sides of the Ashby Coal-field, and on the north side encircles the Charnwood Hills, where it rises to some height at Longcliffe and other points, and forms marked features elsewhere.

The Red Marl occupies the largest portion of this area. It forms the flat plain, little diversified except by syenitic knolls, such as

[1] W. N. Benson, "Preliminary Account of the Geology of the Nundle District, N.S.W.": Report of the Australian Association for the Advancement of Science, 1911, p. 101.

[2] Aided by a grant from the Government Grant Committee of the Royal Society.

Croft, between Nuneaton and Hinckley to the south. It, however, rises to considerable altitudes in the Charnwood region, filling the ancient valleys, and at Bardon Hill fills fissures in the older rocks at 880 feet in the Siberia quarry. At Leicester it is at levels of 100 feet O.D., and further west between Hinckley and Coalville maintains a height of 500 O.D.

The Upper Keuper Sandstone, again, in the same way as the Lower Keuper Sandstone, makes a feature around Leicester, at Ratcliffe and at Croft. So do beds lower down at Orton and Kegworth.

The Tea-green Marls at the outcrop, which is never extensive, form gently rising slopes up to the modified escarpment of the Rhætic beds, which present a broken outcrop along the eastern boundary from Gotham to Glen Parva, forming a narrow band contiguous to the Lower Lias tract east of the Soar Valley and Rugby branch of the Midland Railway. The general trend of the beds is to the south-east. Northwards the Trias is continuous into Derbyshire, the Lower Keuper at Kegworth and Castle Donington being faced by similar beds on the north side of the River Trent at Weston, and the Red Marl stretches beyond the north and east banks of the Trent to Nottingham and Newark. The Lower Keuper and Red Marl on the west are continuous with similar tracts in Warwickshire and Staffordshire (except where faulted down), which in part form a covering mantle above continuous Coal-measure tracts except where these have thinned out, and lie in shallow basins or are cut out by subterranean ridges of igneous or Cambrian rocks.

The Leicestershire Trias is developed by several rivers which cut down to its lower beds in the west, the River Mease, south of Measham, traversing Lower Keuper country, flowing into the River Trent, the River Sence and its tributaries, rising near Bardon, flowing through Red Marl country into the River Anker, a tributary of the River Tame. The River Soar, rising near Sharnford, flows east towards the east boundary near Whetstone, then due north. The Earl Shilton, Glenfield, and Thurcaston brooks flow east into the River Soar, as consequents, south and east of the Charnian range, and north of it the Long Whatton and Garendon brooks flow east into the River Soar near Hathern and Stanford. Thus a radial arrangement of drainage systems is interwoven with an earlier system of strike and dip streams. With the exception of the older rocks forming ridges or isolated hills and the valleys formed by these rivers, the country, save where sandstones locally make escarpments, is extremely uniform, presenting a marked contrast to East Leicestershire with the lofty escarpments of the Lias and Oolites.

Apart from the enormous denudation caused upon the east side by the agency of ice in the Ice Age, there is no doubt that not only the present but also an earlier peneplain existed, when Charnwood was doubtless bridged over by Lias, and even later rocks now removed. Unless such cover existed between Triassic and later times it is difficult to imagine how so long a period, during which they were exposed to denudation, could have elapsed without complete removal of the Trias in Central England. Moreover, in post-Carboniferous

times great denudation occurred, causing inequalities in the Trias floor, and whilst one member was deposited the rest were being likewise denuded in part.

Formerly a great part of this district was covered by the Forests of Charnwood and Leicester, which extended over the entire western half of the county. Now the district is given up to pasture-land with scattered woods and parklands. The soil is sandy in the lower part, and more wooded than in the Red Marl district, which is largely given up to pasture and arable land. The Upper Keuper Sandstone forms hilly districts suitable for the growth of trees, and the soil is grey, a feature serving to distinguish its outcrops from those of the Red Marl. The Tea-green Marl outcrops also give a white soil, and the Rhætic a dark-bluish black soil easily distinguished in the field. On the latter also trees grow well.

The Upper Keuper Sandstone horizons rise to over 400 O.D. in the west, at Orton 400 O.D., 290 feet at Ratcliffe, and 220 feet at Dane Hills. A sandstone lower down at Botcheston crops out at 400 O.D. also, all more or less on high ground.

The Keuper Marl forms high ground at Hinckley, Barwell, and Burbage, south of which it is cut through by the River Soar. North of this also there is a tract 5 to 8 miles wide from Peckleton to Whitwick, where the Red Marls form higher ground, from 400 to 800 feet, than the rest of the country to the south and east, where it lies between 100 and 300 feet.

The hills in the southern part are largely due to river development, south of the River Soar striking north and south, whilst the Upper Soar Valley is free from undulations. The higher ground north of Hinckley and Bosworth is ramified by ridges running east and west, north-east and south-west, and further north by the more or less concentric ridges following the horse-shoe structure of Charnwood Forest, developed partly by modern streams, partly as a result of the ancient contour of the submerged highlands now largely filled in by Red Marl, which in places has again been excavated by the denuding forces of rain, frost, and atmospheric agencies. It is in this upper region that the most complex structure of the Red Marl area is to be met with, and where radial dip and other features play a characteristic part, largely dependent upon the contours of the ancient rocks which have contributed towards the formation of a basal breccia and scree where the two formations are superposed unconformably, as is invariably the case.

The details of the relation of the Charnian rocks to the Upper Keuper Marls and the Lower Keuper Sandstone will be discussed elsewhere.

2. Summary of Previous Work.

Leicestershire has not been wanting in scientific workers in the domain of Triassic geology. Since it occupies so large a portion of the county this would not fail to attract the attention of both local and more general geologists. The list in my bibliography of papers, etc., extends to over one hundred.

Early workers here were J. B. Jukes, who was accompanied by

Sir Roderick Murchison. George Maw paid visits. Professor Hull, in connexion with his survey work, investigated the Coal-field and outlying tracts of Trias, and was much helped by the Rev. W. H. Coleman, of Ashby. Ansted wrote on the district. The Rhætic rocks have been described by Harrison, Wilson, Browne, and others. The Lower and Upper Keuper have received some attention also. Dealing first with the former, J. Shipman, in 1882, noticed the occurrence of galena in the Lower Keuper Sandstone near Shepshed, deriving it from the outliers of Carboniferous Limestone to the north-west. More recently the footprint of a Labyrinthodont, discovered at Kegworth, was noticed in the Report of the British Association on the Flora and Fauna of the Trias by the writer, a description of which appears hereafter.

Papers upon the Upper Keuper have been more numerous. In 1850 John Plant noticed the outcrop of Upper Keuper Sandstone in the New Parks on the Leicester and Burton line, and gave certain tracks, assignable to Crustacea or Annelids, or possibly plant-remains, the name of *Gorgonia keuperi*, which he did not describe, and the name must therefore be regarded as a *nomen nudum*, and disappear, especially as there is no doubt that the fossils in question have nothing to do with Cœlenterata. In 1856 his brother, James Plant, an active local geologist, published a further description of these beds, giving a vertical section (which, however, is wrongly given as north and south, instead of west and east), and a detailed section and lists of fossils. Montagu Browne later (1893) criticizes this paper in regard to these details and as to the continuity of the Upper Keuper Sandstone, east of the River Soar. It was followed by similar accounts of the same beds in Warwickshire by the Rev. P. B. Brodie. George Maw was one of the first to notice the fact that the Charnian system is a buried mountain chain which has been covered up by the Red Marl which surrounds it, except where exposed to denudation and excavated.

The Keuper around Burton-on-Trent and parts of Leicestershire was described in a handbook on that town by W. Molyneux, who made several original observations, noticing the undulations that affect the marls, both red and green, and the existence of *Cheirotherium* footprints on the Ashby Road and near Brizlincote. J. Plant wrote a paper on the occurrence of pseudomorphs of salt crystals in the Red Marl, which in the then state of Triassic knowledge was of considerable importance. We now know they are of universal occurrence at many horizons.

Montagu Browne contributed several papers upon the Keuper around Leicester, of which that published in 1893 was the most valuable, giving more than a hundred sections with useful remarks upon the Trias in the Borough of Leicester. A very full list of fossils is given at the end of this paper also. The critical remarks show that he was well acquainted with the Trias in the field. In a later paper upon the geology of the Beaumont Leys Estate he gave the details of numerous trial-holes made to ascertain the possibility, or rather the reverse, of finding coal on that estate.

Professor W. W. Watts in 1905 published his well-known paper upon the buried landscape of Charnwood Forest, the result of several

years detailed work as a geological surveyor. It gives a succinct account of the relation of the Red Marl to the older rocks so far as the stratigraphical relations are concerned.

A short but valuable paper by W. Keay and M. Gimson upon the relation of the Keuper Marl to the Pre-Cambrian rocks at Bardon Hill throws into light the enormous amount of denudation to which this deposit has been subjected, a fact reflected in the Drift deposits to the south, largely made up of Trias debris. In 1907 T. O. Bosworth wrote upon the origin of the Upper Keuper of Leicestershire, attributing it to desert agency, citing as evidence cases of wind action and other subaerial evidences when in contact with syenitic or granitic rocks. He has pursued this point further in a paper but recently published, but of which I have not seen a copy.

From 1907 to 1909 the reports upon the Trias flora and fauna have contained articles upon the Leicestershire Upper Keuper, summarizing the palæontology of this period. In 1910 the writer's views as to the origin of the Trias, i.e as a delta formation, were promulgated, and though combated at the time appear to be receiving wider acceptance.

The Rhætic beds of Leicestershire have been described by a number of authors. The first published notice of them was by Brodie in 1874, but J. Plant indicated their probable occurrence on the Spinney Hill range in the sixties, a prophecy later fulfilled. It has been stated that Rhætic beds were found by Robert Etheridge at Barrow-on-Soar. If so he never published the fact, but in 1874 H. B. Woodward described a visit with a colleague to compare the Rhætics there with those at Newark. J. Plant also in this year referred in a report upon the Geology of Leicestershire to the occurrence of Rhætics at Leicester. It was not till 1876 that Mr. Harrison published his description with sections and lists of fossils, including *Ophiolepis damesii* and *Pholidophorus mottiana* at Spinney Hills. He assigned, as did others at that time, the Tea-green Marls to the Rhætics. Later the same beds were described by Mr. H. E. Quilter. Edward Wilson had been visiting this district, being then at Nottingham Museum, and he collaborated with the last-named in a joint description of a new section at Glen Parva, which has since been much opened up and presents one of the finest exposures in the country from the Lias to the Red Marl. Messrs. Bates & Hodges described a fresh section at Spinney Hill in 1886. Dr. A. S. Woodward examined the fossil fishes at Glen Parva, regarding them as *Ph. higginsi*, of which *Ph. nitidus* was a small form only.

From 1890 onward Montagu Browne worked hard at the local Rhætics, paying visits to Aust, Watchet, and elsewhere to obtain a wider knowledge of the formation, and established quite a reputation as an authority on the formation for twenty years or more. He found *Ceratodus* in material from Spinney Hill. When the Great Central Railway was being laid down he visited the then fine section of Rhætics at East Leake, at the suggestion of W. T. Tucker, F.G.S., of Loughborough, and obtained quite an interesting series of fossils therefrom. His last paper upon the Rhætics in 1901 summarized all previous knowledge of the Glen Parva section. This

was criticized and amplified recently by Mr. L. Richardson, who asked the writer to check his new measurements, which was done with approval at the time. Since then I have had reason to examine it in greater detail with somewhat different results. Messrs. A. J. S. Cannon and Siddons have recently been examining this section systematically for fossils, and have obtained some very fine and interesting material. Some of this has been described recently, but other material will be alluded to later. The fossil annelid *Archarenicola* is of especial interest, constituting a new type.

Of works dealing generally with the geology of Leicestershire, the earliest is that of J. B. Jukes, who contributed an original and valuable memoir to Potter's *Charnwood Forest*. The Rev. W. H. Coleman, of Ashby, a friend of Professor A. H. Green, who was his pupil, wrote another good general article for White's Directory. Ansted dealt with the physical geography and geology in 1866, but very little of this work was original. *The Geology of England and Wales* in 1876 (and later editions) gives a general description. Harrison in his *Sketch*, 1877, gives a very good and largely original account, with photographic plates, and in 1882 he published his *Geology of the Counties*. An important memoir by Horace Brown on the Permian rocks of the district deals incidentally with the Trias, and is of first importance.

The meeting of the British Association here in 1907 necessitated a local handbook, and the geology was treated by my friend the late Mr. Fox-Strangways and Professor W. Watts. The articles on the palæontology and a bibliography were written by myself. In the same year an account was contributed by Mr. Fox-Strangways for the Victoria County History on the Geology.

The publications of the Geological Survey from time to time on this district deal more or less in detail with each formation. Those that refer to the Trias are Hull's memoirs (1860, 1869), A. J. Jukes-Browne (1885). Mr. Fox-Strangways gave an account of the district in 1900 (Sheet 155), 1903 (Sheet 156), 1905 (Sheet 141), and in 1907 in the descriptive memoir on the Coal-field. In 1909 Mr. Lamplugh described the district north of Melton (Sheet 142), including some parts of Leicestershire. Except in the last case these official survey accounts are lacking in those necessary field details which are so important for purposes of exact correlation.

The following account, therefore, whilst ignoring no previous observations, is more than half based upon original field work and laboratory study during a period dating from 1908, when my investigations in this direction received the aid of a grant from the Government Grant Committee. Until now I have only been able to publish interim reports, or records of isolated pieces of work connected with the investigation. This account, moreover, is a topographical report upon part of the area (Midlands) to be studied. Similar reports upon the adjoining counties are to be published from time to time, and a final report will give an account of the whole district and summarize the chief results of the research. Since the detailed petrographical work will take some time to complete, only a summary is given here.

3. Stratigraphy of the District.[1]

(1) *Castle Donington, Kegworth, Gotham, Loughborough, and Ashby District.*

This area is bounded on the north by the River Trent, on the west by the Ashby and Melbourne line, on the south by the Loughborough and Coalville line, on the east by the River Soar, except the district around Gotham, which, though in Nottinghamshire, is included as allied to the adjoining tract in Leicestershire. Both Lower and Upper Keuper (as well as Rhætics, see 5) are exposed in this area. They abut unconformably upon or lie above pre-Cambrian rocks near Thringstone, Carboniferous Limestone at Gracedieu, Breedon Cloud, Barrow Hill, and Osgathorpe, Millstone Grit at Thringstone and Castle Donington, the Coal-measures around Ashby and Cole Orton, and the Bunter at Castle Donington.

The Lower Keuper Sandstone and Marls as Waterstones are exposed in the north around Castle Donington. Here it forms a ridge which rises above the pebble beds at the north end of the Quarry Hill Plantation, along the banks of the Trent. The marls at the base are fairly thick, and are overlaid by about 80 feet of brown and yellowish evenly bedded sandstones, fine-grained and fairly hard when weathered, divided by flaggy green marl with ripple-marks. They form quite an escarpment on the north of the village. Though Mr. Harrison has stated that there is no breccia here, the basal beds are decidedly brecciated with a few pebbles also. A fault to the east has thrown down the sandstones. Quarries have been excavated in the sandstones which are used for building as at Weston. The marls afford a heavy loamy soil. Westward these beds may be traced north of Donington Park along the Trent as far as Melbourne. At the gasworks the dip was 14°, and the sandstones overlaid Millstone Grit dipping at 35°.

The Rev. A. Irving has reported the occurrence of a footprint of *Cheirotherium* at Castle Donington, but this probably refers to Weston, on the opposite side of the Trent, where they have been found recorded as *Labyrinthodon*. The sandstones here are thick-bedded, full of drusy cavities, like the Upper Keuper Sandstones. The overlying marls are flaggy and covered with ripple-markings, sun-cracks, rills, and rain-drops, as at Kegworth, where a similar footprint was found. The section shows 20 feet of white, grey, and brown sandstones, with flaggy marl partings. The sandstones are soft, but are quarried by the Midland Railway Company, who have a quarry at the junction. The joints of the rock are coated with manganese.

East of Castle Donington, as remarked, at Hemington the sandstones are let down, and Keuper lies against the sandstone scarps. On the downthrow side the height of the country is maintained by a sandstone in the Red Marl similar to that at Donington Park and Kegworth. Gypsum has also been noticed.

Eastwards the Lower Keuper Sandstone is lost sight of till it is exposed at Kegworth, where it forms the base of the hills on which the higher part of the town is built. Many exposures of these beds

[1] This is divided into five distinct areas for convenience.

have been noticed here, and the sandstone, which is pink in colour, has also been quarried to some extent. It is overlain on the north by alluvium and river-gravels, and to the west the Red Marl rises above it, a lobe near the windmill running out due east, whilst Red Marl also comes on to the south.

In recent excavations for sewers the marly beds with sandstones were exposed in the Loughborough Road during excavations for the Derwent Valley Water Board. A footprint of *Cheirotherium* was discovered here thirty years ago, in excavating at a depth of 3 feet in sandstone proved to a depth of 3 ft. 6 in., which runs out 700 feet north of the post office. The beds dip south-east. A spoil-heap of the marls and sandstones showed that they were abundantly ripple-marked, some of the ripples bifurcating with a variable distance between the crest and furrow. In the latter there were sun-cracks, which occurred also separately. Here and there rill-marks and rain-pittings occurred. A specimen showing pseudomorphs of salt crystals was obtained. The sandstones in these instances were grey and green, the marls reddish. A geode containing gypsum was found, and a quartzose pebble 5 by 3 inches.

Where the Lower Keuper Sandstones crop out beneath the Red Marl on the west from Melbourne southward they are of little extent in this area, though they spread westward for some distance. They may be traced along the line of railway, being exposed here and there, lying over the Carboniferous Limestone at Breedon Cloud. From Worthington to Thringstone they form high ground overlooking the Coal-measures around Ashby, which are faulted against them, a ridge running north-west by south-east. Between Griffy dam and Thringstone the base is a well-marked breccia, which is thicker than the overlying sandstones, being exposed in several places. The sandstones with a breccia at the base are seen at Gracedieu overlying the limestone shales.

At and around Cole Orton the beds rise above the Middle Coal-measures, as in North Staffordshire, in little hillocks, forming picturesque country. In the Leicester and Burton railway cutting at Breach Hill sandstones crop out above the coal-seams. There is some boulder-clay and sand on the higher ground here which obscures it, but it crops out in the valleys cut through by the streams.

Though the greater part of the beds above the Coal-measures around Ashby have been denuded, to the north-west there is an extensive patch of Lower Keuper Sandstone overlain by glacial clays and sands, which is here an outlier, giving rise to a well-marked feature with a noticeable scarp, except in the neighbourhood of Lount on the east, and on the north, east of Hartshorn. About Smisby and Pistern Hills[1] Drift overlies it, but at the former place white sandstones crop out with interbedded Red Marls. The beds are about 80–100 feet thick here, with red marly beds below and brown and yellow sandstones with flaggy partings. To the west of Ashby a fault brings in some Permian beds near the station in the

[1] A boring here proved Lower Keuper Sandstones and Marls, lying on Coal-measures with no intervening Bunter, which is overlapped by the former very widely.

railway cutting, where 2–3 feet of red and purple speckled sandstones overlie red and purple marl with nodules of hæmatite. East of these exposures the Red Marl forms a wide tract extending northwards to the River Trent and on the east to the River Soar, bounded on the south by the Loughborough line.

Though there is little Drift in this area except south of Diseworth and just north of Ashby the country is not very elevated. The contour-lines range between 200 and 300 feet as a general rule. Around Ashby the anticlinal of the coal-basin causes a slightly higher elevation up to 450 feet. In spite of this there is little variation in the general features of the Red Marl. Only a few disjointed exposures of stronger features caused by sandstones are revealed. As elsewhere in Leicestershire, the skerries exposed in pits and similar sections do not as a rule form any feature, except locally, as along the Midland Railway between Kegworth and Hathern, and on a smaller scale on the Great Central Railway near Loughborough. This is due to the general absence of flexures (upon which remarks are made later). Consequently, as observed by Mr. Fox-Strangways, it has not been possible to trace the several dominant skerries. The one cropping out on the Midland Railway is probably the second band, which lies 200 feet below the Tea-green Marls. The sandstone horizons traceable near the base of the formation belong to a series of three, the first of which lies 50 feet above the waterstones. That at Diseworth occurs as an inlier.

In the north-west of this area the Red Marl occurs as outliers south-east of Melbourne southwards to Worthington, forming slight eminences between the 200 and 300 contour-lines overlying the inliers of Carboniferous Limestone at Breedon Cloud and at Barrow Hill and Osgathorpe, two or three feet of Red Marl with a limestone breccia at the base irregularly bedded lying unconformably upon the limestone. About here are indications of the lowest skerry band.

The same skerry may be traced to the north, where at Donington Farm a bed of sandstone in the Red Marl can be followed northwards to Donington Park, where just east of King's Newton it strikes due west, and south of Weston it turns north and then thickens considerably, and striking north-east it thins out again, following the outcrop of the Red Marl in a sinuous course along the River Trent. At King's Mills it turns back south-east as far as the south boundary of the park, where it again, after a short distance, is to be traced north-west till it turns again to the east, then north-west, and finally can be followed in a south-east direction up to the Castle Donington road. A small quarry was opened up for building-stone near the gardens. Below this horizon the Lower Keuper Sandstone forms a marked feature. There are thus two terraces flanking the Trent, with plateau-like hills to the south. Eastward this sandstone follows an easterly course, till at Lockington Grange, where it dips to the south-west at 3°, it thickens out, forming a marked feature to Broad Hill, south-west of Kegworth, where it thins out again, and being lost in the Soar Valley is found to dip 5° due west. At Kegworth it has been quarried for mending roads, and is there 40 feet from the base of the Red Marl. In exposures in the

brickyard to the south it is seen to consist of fine-grained white argillaceous sandstone about a foot thick, with greenish-blue marly beds, containing ripple-marks and pseudomorphs of salt crystals.

South-west of Kegworth the same sandstone, which is here fairly thick, is exposed in the valley of the Long Whatton brook south of Diseworth, and is an inlier, brought to the surface by the cutting back of the Red Marl and possibly as a result of some fold in the Red Marl which has brought it up to a higher level. A flexure is noticeable in its outcrop near Lockington Grange which may be connected with this.

East of the River Soar the Red Marl forms high ground east of the Soar Valley. From Red Hill on the Midland Railway to Thrumpton gypsum crops out continuously, and is found at the base of the two outliers of Rhætics and Lower Lias north of West Leake and about Gotham. At the last place the gypsum beds form an important feature and are worked by tunnels driven into the sides of the hills. They are generally continuous, but are dissolved in places by water which accumulates at this horizon, and marl fills the intervening spaces and is left as pillars in the workings. The Tea-green Marls crop out at Winking Hill close to the road at the south end of the northern outlier.

At the Gotham Plaster Company's works the gypsum[1] is 8 feet thick, sound and clear white, and is overlain by Red Marl, but a little grey or green marl is mixed with the less pure parts. The gallery is driven in a southerly direction for half a mile. It is ground for plaster here, as at the other pits in this district. At Shepherd's Pit to the north a similar tunnel is driven for half a mile into the hill. The gypsum is more or less horizontal, and is 8 feet thick, thinning out in places and becoming useless, as at Thurmaston.

At West Leake the Red Marl forms an outlier as in the north. To the west it is covered by river-gravels, and forms low ground, to the east by lacustrine clay at Gotham Moor, beneath which the gypsum crops out. Except along the escarpment, where sections have been cut for gypsum, there are few exposures. At Sharpley Hill the gypsum is at a lower level,[2] that at Gotham being below the Newark gypsum beds also. The Tea-green Marls crop out in the Great Central Railway at Crow Wood, and are seen again in the cuttings at White Hill, East Leake.

There is a pit west of Hutchley's Mills which shows 41 ft. 4 in. of Red Marl with two bands of ball gypsum 8 inches thick and green marl 5 feet thick as at Gipsy Lane, just below Tea-green Marls. There is no exposure at Hutchley's Mills, but the gypsum is worked by a tunnel driven more or less east into the hill. The track descends at first abruptly, but the workings, which continue for nearly half a mile into the hillside, are ultimately horizontal. The gypsum is similar to the ball gypsum of Knighton, and is ground for plaster. Pseudomorphs of salt crystals occur on the green marl.

The band of skerry which may be traced along the east side of the Midland Railway for a long distance is higher up than the Kegworth

[1] It is practically pure alabaster.

[2] 180 feet below the Rhætics at East Leake.

Beds, and is the same as a bed seen in the brickyard at Hathern. The bed exposed in the cutting of the Great Central Railway to the east is probably on a higher horizon and may represent the Dane Hill Sandstone in an attenuated form. In the brickyard there is a section 63 ft. 7 in. of red and green and white marl with two thick skerries and thinner green bands, with ripple-marks.

A boring in the brickyard passed through 48 feet (dug well), Red Marl 228 feet, sandstone and marl 126 feet, and ended in Forest rocks. In a second boring south of the village, below 110 feet Red Marl and 140 feet Lower Keuper Sandstone, 256 ft. 4½ in. Bunter and 362 feet of Carboniferous Limestone Shales and Millstone Grit were met with.

In regard to the Bunter limits, Fox-Strangways considered "they were not deposited much to the east of a line drawn through Castle Donington and Ashby, though the boring at Hathern shows that they were abnormally thick in what is now the valley of the Soar". De Rance remarks, "The eastern boundary of the outcrop of the Pebble Beds of the Bunter ranges along the River Trent, past Nottingham, as far as Stanton and Swarkeston. Eastward of this line the Keuper Sandstone rests on the Coal-measures of Ashby-de-la-Zouch and the Carboniferous Limestone of Breedon Hill. Ranging parallel to this line and eastward of it, the Lower Keuper Sandstone building stones and conglomerate thin out, being last met with at Hathern, ranging north of Charnwood and Atherstone. South of Nuneaton fine-grained white sandstone used for building occurs, interbedded with evenly bedded shale of the waterstones."

Horace Brown remarks that the Permian too, in Leicestershire, is not met with east of Packington. There is thus abundant evidence that the Trias deposits overlap each other in all directions, the newer divisions transgressing upon older rocks beyond the area of the newer divisions, indicating a considerable subsidence during this period. Whilst the Lower Keuper is slightly thicker in some directions to the south-east it attains its maximum at Hathern, and though there is a south-easterly attenuation of the Trias generally around the older rocks there is, especially in this area, a thickening of the deposits eastward, borings at Leicester showing a thickness of over 600 feet.

The borings at Piper Wood, north of Shepshed, are difficult to correlate, but there appears to be here, as at Hathern, underlying the Red Marl a considerable thickness of Millstone Grit, and possibly Carboniferous Limestone Shales. Taken with the outcrop of Millstone Grit at Castle Donington, it would seem that there is an anticlinal of the Carboniferous rocks, perhaps, related to an older anticlinal of Charnian rocks running north-west by south-east, and to this we may attribute such evidence as there is of flexures in the Red Marl, forming the Diseworth inlier. This was produced in post-Triassic times along a fold which had previously, and has since, been subjected to renewed activity. Between here and Loughborough much more drift obscures the Red Marl, and exposures are few. Here the Red Marl is thicker and dips south-east at a low angle. In a few brick-yards in the town the marls are used for brick- and tile-making, but

are usually covered by alluvium and river-gravels. So that sections made during the construction of the Great Central Railway and in the town have revealed nothing of importance. From Normanton Hills southward the section is in Red Marl, up to the Soar Valley, just opposite the Loughborough Road. In a cutting a bed of sandstone 3 feet thick, dipping to the north at 1°–2°, was encountered. At Nottingham Road the marl was 8 feet thick, at the Midland Railway 14 feet, and at the Canal 12 feet.

Turning to the surrounding area, it may be noted that the gypsum at Chellaston where alabaster is obtained is 6 to 12 feet thick. The Red Marl forms a feature, and in the overlying Drift Foraminifera were obtained, once thought to be Triassic.

At Chilwell,[1] to the north, a thick band of sandstone near the base is brought up on the south side of a fault, and is 20 to 30 feet thick, and resembles the Dane Hill Sandstone. A band of skerry near the base of the marl here is traceable from Derby to the Erewash Valley. In the Sandstone salt pseudomorphs are abundant.

A boring at Clifton Colliery showed 157 feet of Red Marl overlying the Coal-measures. At Ruddington there was 386 feet of Red Marl, 75 feet Waterstones, 218 feet Bunter, above Coal-measures dipping at a high angle. At Owthorpe there was 12 ft. 6 in. Lias, 34 ft. 6 in. Rhætics, 633 feet Red Marl, 125 feet Lower Keuper, 428 feet Bunter, overlying Coal-measures.

At Melton Mowbray the section was—

	Feet.
Loam and gravel . . .	14
Boulder-clay	24
Lower Lias	230
Rhætic	16·4
Upper Keuper (Tea-green, 24 feet)	248
	532·4

This shows that while in Leicestershire the Bunter thins out eastward, northwards there are deep hollows in these beds, and that they thicken eastward locally, thinning southward. The Lower Keuper also thickens eastward, but to a less extent.

(*To be continued in our next Number.*)

REVIEWS.

I.—Development and Systematic Position of the Monticuliporoids. By E. R. Cumings. Bulletin of the Geological Society of America, vol. xxiii, pp. 357–70, pls. xix–xxii, 1912.

THE systematic position of the Monticuliporoids has long been uncertain. Considered by Nicholson as 'Tabulate' Corals, they were generally so regarded. Ulrich, and after him Bassler, American specialists in Palæozoic Polyzoa, claimed them for their group; and

[1] A boring here passed through Red Marl and Sandstone 167 feet, Pebble Beds 258 feet, Soft Sandstone 33 feet, and 877 feet of Coal-measures.

palæontologists nowadays place them, usually with some hesitation, among the Polyzoa. Eastman in his translation of Zittel's *Grundzüge der Paläontologie* takes the original course of placing them under both Corals and Polyzoa. Still more startled were palæontologists when a letter written by Kirkpatrick to *Nature* appeared,[1] stating that Monticuliporoids were allied to *Merlia*, a recent siliceous Sponge. "The discovery," says Kirkpatrick, "of the solution of the problem of Merlia is destined to prove of profound importance to palæontologists. For I have now convincing proofs . . . that numerous Palæozoic fossils coming under the old-fashioned term 'Monticulipora' are essentially the same nature as Merlia, and that they are supplementary calcareous skeletons of siliceous sponges. Merlia seems to be a solitary survivor of the Monticulipora type from Palæozoic times . . ."

Now it was obvious that, if *Merlia* were a siliceous Sponge and the Monticuliporoids allied to it, the post-embryonic development would be similar in both cases, whereas if Monticuliporoids were Polyzoa they should present post-embryonic stages characteristic of that phylum. What was required, then, was the determination of the early stages of Monticuliporoids. This was meanwhile being done, quite independently of any thought of *Merlia*, by Cumings in America, with the result that, in the same month as Kirkpatrick's letter in *Nature* appeared, there was published an account by Cumings of the early stages of certain Monticuliporoids, showing them to agree closely in this direction with Cyclostome Polyzoa.

The genera in which Cumings has shown Polyzoan growth-stages from the time when the larva first became fixed are three—*Prasopora*, *Phylloporina*, and *Callopora*; but in four other genera he has found very early, though not the earliest, stages, which leave no doubt that these four genera are of the same nature as the first three. It is unfortunate that Cumings makes no mention of the earliest stages of *Monticulipora mammulata*, the genotype of *Monticulipora* chosen by Nicholson[2] from the four genosyntypes presented by d'Orbigny.[3] For it is possible, though unlikely, that included among the Monticuliporoids are forms not related to the Polyzoa; and it is the genotype of *Monticulipora* that Kirkpatrick claims as related to *Merlia*. Now, should this prove to be anything but a Polyzoan, the name Monticuliporoid, used, apparently, by Cumings as synonymous with Trepostome, will have to be abandoned to whatever group includes *Monticulipora mammulata*.

If, as is likely, *Monticulipora mammulata* is proved to be symphyletic with the genera that Cumings has conclusively shown to be Trepostomes, it presents in its skeleton a very pretty example of homœomorphy with *Merlia*.

It is important to appreciate the nature of Cumings' evidence. Four Polyzoan orders are well known as fossils, namely, Cyclostomata, Trepostomata (including Monticuliporoids), Cryptostomata, and

[1] *Nature*, vol. lxxxix, p. 502, 1912.

[2] Nicholson, *On the Structure and Affinities of the genus Monticulipora and its sub-genera*, 1881, p. 1.

[3] D'Orbigny, *Prodrome de Paléontologie stratigraphique universelle*, vol. i, p. 25, 1850.

Cheilostomata; and of these the last three may be derived each independently from the first. It is to the Cyclostomes, then, that we look for the primitive and typical development. Barrois[1] and Harmer[2] have each worked out in detail the development of *Tubulipora*, a recent Cyclostome of primitive standing. But, as far as the skeleton is concerned, the earliest stages can be studied with ease in the still more primitive Stomatoporas well preserved as fossils in British Jurassic rocks.[3] On settling, the Polyzoan larva secretes a shell of spherical shape—the protœcium,[4] from which springs the first individual—the ancestrula.[5] In the most primitive forms (*Stomatopora*) the ancestrula gives rise to one or two buds; in the more advanced though still primitive forms (*Berenicea*, *Tubulipora*) three buds spring from the ancestrula, and these in turn give rise to a varying number. In *Berenicea* and other discoid forms the later buds curl round and may cover the protœcium and often the ancestrula too; and this tendency has caused difficulty in demonstrating the protœcium in certain Palæozoic forms. Generally speaking, then, the typical early stages of the Cyclostome appear as an ancestrula with a bulbous proximal end (the protœcium) and with one, two, or three distal buds. The Cryptostomata show similar stages before taking on characters peculiar to themselves.[6] In the Cheilostomata development is condensed by tachygenesis, in accordance with their specialization, to such an extent that the protœcium is merged in the ancestrula,[7] which itself has already lost the primitive tubular form. Among the Trepostomata Cumings has now demonstrated the globular protœcium and ancestrula with three distal buds in *Prasopora*, *Callopora*, and *Phylloporina*, and the post-protœcial stages in *Peronopora*, *Rhombotrypa*, *Amplexopora*, and *Homotrypa*; in *Rhombotrypa* and *Amplexopora*, however, the ancestrula apparently gives rise to two buds only.

It is now possible to form some idea of the inter-relationship of the four Orders. The Cyclostomes undoubtedly are the most primitive, since they alone show the complete demarcation between the protœcium and ancestrula—the two appear as separate entities. The Trepostomes show early stages exactly comparable with Cyclostomes, except that the demarcation between protœcium and ancestrula is hardly to be seen, the latter appearing as the distal end of the former. The characters separating Trepostomes from Cyclostomes concern the characteristic habit of growth, the nature of secondary skeleton, and matters of heteromorphism; but the tubular zoœcium and simple

[1] Barrois, *Recherches sur l'embryologie des Bryozoaires*, 1877, pp. 70–85, pls. iii and iv.

[2] Harmer, "On the Development of *Tubulipora*": Quart. Journ. Micros. Sci., vol. xli, pp. 73–157, 1898.

[3] Lang, "The Jurassic forms of the 'genera' *Stomatopora* and *Proboscina*": GEOL. MAG., Dec. V, Vol. I, pp. 315–22, 1904.

[4] Cumings, "Development of some Palæozoic Bryozoa": Amer. Journ. Sci., ser. IV, vol. xvii, p. 50, 1904.

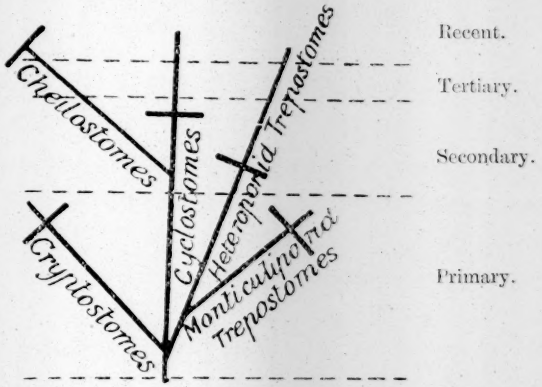
[5] Jullien, *Mission Scientifique du Cap Horn, 1882–3*, tom. vi, Zoologie—Bryozoaires, p. 29, 1888.

[6] Cumings, op. cit., pp. 58–74, 1904.

[7] Cumings, "Development of *Fenestella*": Amer. Journ. Sci., ser. IV, vol. xx, p. 170, 1905.

aperture are retained by both. Their ranges are conterminous, though the Trepostomes reached their maximum in the Palæozoic, are rare in Secondary rocks, and hardly ever found in Tertiary and Recent times.[1] The Cyclostomes, on the contrary, reached their maximum in Cretaceous times and are very abundant now. Cumings' view is that "the two orders are cognate and do not stand in linear relation one to the other". This can mean only that when a common ancestor is reached, Cumings would consider it neither a Trepostome nor a Cyclostome. I should rather regard it as a Cyclostome, and say that the Trepostomes branched from the Cyclostome stock at a very early date.

In their earlier stages the Cryptostomes resemble the last two orders, but there is a greater condensation of the protœcium and the ancestrula—the latter appearing merely as a distal appendage of the former.[2] They may be, therefore, an independent offshoot of the Cyclostomes, as Cumings regards them,[3] or a side branch of the Trepostome stock soon after these had diverged from the Cyclostomes. Cryptostomes are confined to the Palæozoic.



Cumings is inclined to regard the Cryptostomes as 'Palæozoic representatives' of the Cheilostomes,[3] that is to say, presumably that, with their modified apertures, they fill the same bionomic role alongside the Cyclostomes as do the Cheilostomes at the present day, and not that the Cheilostomes are their linear descendants. The earliest stages of those Cheilostomes in which these have been investigated show the protœcium completely merged in the ancestrula—they become identical. Except for the isolated record and figure by Lamouroux[4] of *Onychocella* from the Jurassic Calcaire à Polypiers of

[1] What are here considered as the post-Palæozoic Trepostomes are the Heteroporidæ, Cerioporidæ, and their allies.

[2] Cumings, loc. cit., 1905.

[3] Cumings, op. cit., p. 76, 1904.

[4] Lamouroux, *Exposition Méthodique des genres de l'ordre Polypiers*, 1821, p. 113. The three specimens mentioned in the British Museum Catalogue of Jurassic Bryozoa, 1896, as coming from the Norman Calcaire à Polypiers are not free from doubt; one certainly and another probably are from the Cretaceous of Maastricht.

Normandy, the first Cheilostomes are found in the Cretaceous and never are abundant until the Cenomanian; they are at their maximum to-day. It is probable that they too had an independent origin from the Cyclostomata. The diagram on p. 35 suggests these relationships; the divergence of the lines from the normal represents a corresponding degree of specialization; and the transverse lines show the point at which the group reached its maximum.

I have attempted in this review to bring Cuming's paper into relation with the general question of Polyzoan relationship and to demonstrate its importance to the subject at large. It appears to be a distinct forward step, and in its far-reaching results has a right to be considered a very marked success of the onto- or rather in this case the asto-genetic method.

W. D. Lang.

II.—The Work of Rain and Rivers. By T. G. Bonney, Sc.D., LL.D., F.R.S. 8vo; 144 pages, with 19 text-illustrations. Cambridge: at the University Press, 1912. Price 1*s.* net.

THE aims of the Cambridge Manuals of Science and Literature are by now become fairly widely known, and the present volume is likely to be successful in rendering available to persons of ordinary education a digest of observations made during many years by the "veteran tourist", Professor Bonney. As the author tells us, the volume is not calculated to contain new information, but his authority and experience, it may be added, are a sufficient guarantee that nothing of essential importance has been omitted. Four chapters are devoted to the subject of "Rain and Rivers", and a fifth is a résumé of the history of "Man's Learning of Nature's Lesson".

In "Carving and Carrying", as the first chapter is termed, we find reference to the familiar 'pipes' in the Chalk and to operations of meteoric agents on a small scale, such as may commonly be seen in all parts of England. For many of his illustrative examples, however, the author takes us farther afield, and not unnaturally makes frequent reference to the Alps.[1] It is possible, indeed, that the detailed descriptions of some not generally well-known districts may fail to commend themselves to the ordinary reader. In the case of a more complicated topic like the history of a river-system it is an advantage, as the author points out, to discuss foreign examples first, because their history is "written in bolder characters and in plainer terms. . ." The chapter on the making of valleys is a very clear exposition, and contains a large amount of information. The following one, on transport and deposit, furnishes various statistics of interest.

The last chapter traces the history of "Man's Learning of Nature's Lesson" from the times of Herodotus and Strabo through those of Hutton and Playfair to the present day. In animadverting on the work published in 1857 by Colonel George Greenwood (the "father of modern sub-aerialism" as Mackintosh styled him), Professor

[1] [See review of Professor Bonney's latest book, *The Building of the Alps*, Geol. Mag., December, 1912, pp. 564-6.—Ed.]

Bonney quotes somewhat discursively from contemporary opinion—not always a safe criterion. It is unfortunate that the author should not have observed the additional testimony of the review from which he gives an excerpt that this earlier writer "must be credited with the merit of having been the first of late years to give to the world . . . a clear exposition of the sub-aerial theory of denudation".[1]

The illustrations are limited to nineteen in number, and, it must be confessed, afford scope for improvement; but of the text of this book it may unhesitatingly be predicated that it will help its readers "to understand better and regard with deeper interest" the earth on which they live.

III.—A Textbook of Palæozoology.

Lehrbuch der Paläozoologie. By Professor E. Stomer von Reichenbach. Erster Teil: Wirbellose Tiere, pp. x, 342, with 398 figures (1909). Zweiter Teil: Wirbeltiere, pp. viii, 325, with 234 figures (1912). Leipzig: B. G. Teubner. Price 10 marks each volume, cloth.

THIS textbook differs from the majority of recent palæontological textbooks in that it does not, as a rule, give diagnoses of genera, but usually confines itself to orders and higher divisions. It has the advantage of being much more readable, but the drawback is that it cannot be used for determining genera. In the first volume, after an introduction of twenty-eight pages dealing with the condition and preservation of fossils, the skeleton, etc., the Invertebrata are described. After the description of each phylum, sub-phylum, or class, a short diagnosis of its subdivisions, a graphic table of their distribution in time, a section on their geological occurrence and evolution and a bibliography are given. In the second volume, after an introduction of thirteen pages, the Vertebrata are similarly treated.

At the end of the second volume sixty-three pages are devoted to concluding remarks on the succession of faunas, the geographical distribution and œcology of animals in the geologic past, palæozoology and the theory of evolution, death and extinction, and the literature of these subjects. Considered as a whole the work is much more attractively written than most German textbooks. It is very well printed and both volumes are excellently illustrated with a great number of recently described fossils, and there is a good index to each.

B. Hobson.

IV.—The Structure of the Earth. By T. G. Bonney, Sc.D., F.R.S. 8vo; pp. 1–94. London: T. C. & E. C. Jack, 1912. Price 6*d.* net.

POPULAR exposition of geological science is now receiving due attention, and it is fortunate that such an experienced teacher as Professor Bonney should have undertaken to write this small volume for "The People's Books" series. The subject is introduced

[1] Geol. Mag., 1867, p. 412.

by a consideration of the problems and methods of geology, and the attention of the lay reader is at once engaged by the mention of familiar geological phenomena. The author then proceeds to discuss the constitution and age of the earth. He gives a clear idea of the relations in size and distance of various members of the solar system, but, very wisely perhaps, refrains from discussing the origin of our planetary system, commencing his story with the earth as a glowing mass. We then see the origin and nature of the present crust of the earth. The various agencies that have affected its configuration—heat and cold, running water, snow, ice, and the sea—are interestingly considered, and a short chapter is devoted to a very clear account of volcanoes. The occurrence of marine fossils at great heights on the earth's surface, among other phenomena, is then referred to in proof of the changes that have taken place in land and sea; and finally we have a review of the succession of life on the earth. Additional value is given to this work by the inclusion of a well-arranged bibliography.

V.—Dana's Manual of Mineralogy. Thirteenth Edition, entirely revised and rewritten by William E. Ford. 12mo; pp. viii, 460, with 10 plates. New York, John Wiley and Sons; London, Chapman & Hall, 1912. Price 8*s*. 6*d*.

THE revision of this well-known manual will be very welcome, for although the book has been frequently reprinted it is twenty-five years since the text was revised. The present volume is arranged on the same plan as formerly, but there are some necessary omissions and not a few useful additions. Thus we find that the chapter on petrology has been excluded, but there is a useful account of the occurrence and association of minerals. There is less detail in the descriptive portion of the book, and the catalogue of American localities is omitted—changes that will be quite in keeping with the requirements of the general student. As new features we note the useful list of minerals arranged according to systems of crystallization, and the statistics of mineral production in the United States for 1910. The tables for the determination of 203 species are decidedly useful in their new form, and the ten photographic plates make a good addition. The book is well printed, contains 357 text-figures, and has a convenient index; printers' errors are rare, although we observe a misspelling of 'cryptocrystalline' on p. 176. We now have several excellent elementary manuals of mineralogy, but the present volume will take a high place in making the Dana series complete.

VI.—Brief Notices.

1.—The Beginner's Guide to the Microscope. By Chas. E. Heath, F.R.M.S. 8vo; pp. 1–119, with 46 text-illustrations. London: Percival Marshall & Co., n.d. Price 1*s*. net.

THERE is no pretence in this little book of giving instruction in scientific microscopy: its aim is purely to teach the beginner to use the instrument as a means of recreation. As an introduction

to the essentials of a modern microscope, however, it should prove of distinct use. The various parts of the instrument and their uses are described, and the subject of illumination is well dealt with. The hints given regarding the choice of a microscope are likely to be of value to the class of readers for whom the book is intended, and the same may be said with respect to the instruction given on the mounting of objects. To readers taking up the study of petrology, however, the book could scarcely be recommended as comprehensive. An account of the camera lucida would not have been out of place.

2.—The Origin and Evolution of Primitive Man. By Albert Churchward, M.D., F.G.S. Crown 8vo; pp. 88, pls. 46. London: George Allen & Co., Ltd., 1912. Price 5*s*.

THIS is a discursive little book specially devoted to pointing out the so-called mistakes of 'authorities'. The writer asserts that "it was in Africa that the little pygmy was first evolved from the *Pithecanthropus erectus* or an Anthropoid Ape", and then gives some account of the African pygmies as the survivors of the earliest type of man. He thinks that the skeleton lately discovered near Ipswich is probably that of a Nilotic negro, though he "cannot positively say if this was a man of late exodus of the Nilotic negro, or one of an early exodus of Stellar Mythos". Notwithstanding the beautiful photographs of implements and primitive peoples with which the book is illustrated, we fear it will scarcely commend itself to geologists.

3. Geology of Egypt.—Attention was called (Geol. Mag., 1910, p. 571) to the issue of two colour-printed geological maps of Egypt, by the Survey Department, Cairo; one on a fairly large scale in six sheets and the other in one sheet. The Department has now (1912) issued *Explanatory Notes to accompany the Geological Map of Egypt, with tables showing distribution of geological formations and economic products*. The work is written by the Director of the Geological Survey, Dr. W. F. Hume, and it contains a concise account of the geological features and history of the formations, illustrated by two plates of longitudinal and vertical sections. As a guide in the field, and for reference, this thin volume will be of great utility.

4. Croydon Natural History and Scientific Society.—The Proceedings and Transactions of this Society for the session 1911–12 contain the Address of the (now past) President, Mr. W. Whitaker, F.R.S., entitled "Surrey Geology in the past Eleven Years". In this is given an exceedingly useful record of the works published (with comments), thus continuing the record of subjects dealt with in the previous geological addresses (1900–1) by the same President. Dr. H. Franklin Parsons, F.G.S., was elected President for the session 1912–13. He has contributed to the volume an important paper on "The Flora of the Commons near Croydon", with notes on the physical features and geology of the several areas.

REPORTS AND PROCEEDINGS.

I.—The Cambridge Philosophical Society.

On a remarkable instance of complete Rock Disintegration by Weathering. Abstract of a paper read by Dr. F. H. Hatch before the Cambridge Philosophical Society on November 25, 1912.

THE material described comes from Diamantina, in the province of Minas Geraes, Brazil, where it is being worked for diamonds. It occurs as a loose sandy deposit in which there are a number of partially disintegrated pebbles, and is sufficiently soft to be dug out with the shovel at the lowest depth yet attained in the open-working.

The pebbles consist of quartzite, vein-quartz, steatite, and tourmaline-quartz vein-stuff. The sand is a mixture of colourless quartz and of the fine powder produced by the pulverization of the steatite fragments. The heavy minerals in the residue obtained by treatment with bromoform, are the following: zircon, zinc blende, galena, iron pyrites, chalcopyrite, rutile, and tourmaline.

The material has evidently resulted from the prolonged weathering of an ancient conglomerate formation. The weathering agents have not only removed the cement of the conglomerate, but have also abstracted the material that originally cemented the constituents of the quartzite pebbles, which have consequently been reduced to a friable condition, and can even be crushed to powder between the fingers.

The diamonds, which occur in the following forms—octahedron, rhombic dodecahedron, three-faced octahedron, and six-faced octahedron, have a characteristic greenish tint, seen under the microscope to be due to the presence of small spots and flecks of some chloritic mineral. It is, however, only 'skin-deep', the cut stones being perfectly clear and colourless.

II.—Geological Society of London.

November 20, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Hafslo Lake and the Solvorn Valley (Norway)." By Horace Woollaston Monckton, Treas.L.S., F.G.S.

The district dealt with lies north of the main Sogne Fjord and west of the Lyster Fjord. Attention is drawn to a series of valleys running from the area of the Jostedal snowfield and cutting the belt of Silurian rocks which crosses the district in a north-easterly and south-westerly direction, and to a second series of valleys which run parallel to the snowfield and to the Silurian belt. The author traces the valley of the Vejtestrands Lake, which belongs to the first of the above series, until it reaches the Hafslo Lake, which lies at a point where the valleys of the two series intersect. The present line of drainage follows a valley of the second series from the lake to the fjord, but a disused outlet from the lake to the fjord is described belonging to the first series. The author, while thinking

that the disused outlet is probably the older of the two, gives reasons for believing that both outlets were in use perhaps simultaneously during the latter part of the Glacial Period, when a glacier filled and overflowed the basin of the Hafslo Lake.

The author describes some giants' kettles and other examples of erosion by water, which for various reasons he believes to date from a time when the glacier extended to the places where they are now found, and it is suggested that they were the work of a river flowing under the ice or between the ice and the rock.

2. "On the genus *Aulophyllum*." By Stanley Smith, B.A., M.Sc., F.G.S., Clare College, Cambridge.

Aulophyllum is a genus belonging to the Clisiophyllid group. It is found in the Upper Beds of the Carboniferous Limestone Series in Britain and on the Continent. It appears in the lower part of the *Dibunophyllum* zone (D_1), becomes common in the middle subdivision of the zone (D_2), and is plentiful in the highest limestones investigated (D_3).

The coral was first described by David Ure, in 1793, as *Fungites*; the genus was established by Milne-Edwards & Haime in 1850. The author includes in this genus Thomson's genus *Cyclophyllum*. The genus is described in detail, and then the ontogenesis is discussed. The development of the various items of coral anatomy is first treated; and the author subsequently deals with the growth of the coral considered as a whole, six stages being recognized by him. The forms found in D_1 do not advance beyond stage *d*.

Structural variation is then considered. The author regards all the species previously described as variations of the same species, but recognizes several well-marked types and a number of time mutations. Many specimens of the coral display the phenomenon of rejuvenescence. The structural changes observed are described, and the nature of the rejuvenescence is briefly discussed.

December 4, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Lower Palæozoic Rocks of the Cautley District (Yorkshire)." By John Edward Marr, Sc.D., F.R.S., V.P.G.S.

The following classification is suggested for the Ordovician rocks of the district:—

Ashgillian.	Ashgill Shales.	
	Beds above the Volcanic Group.	*Staurocephalus* Beds.
	Contemporaneous Volcanic Group.	
	Beds below the Volcanic Group.	
	Phacops robertsi Beds.	
Caradocian.	*Calymene* Beds.	

The *Phacops* and *Calymene* Beds are remarkably similar in lithological characters (dark calcareous shales and impure limestones), but the palæontological change is at the top of the *Calymene* Beds, and the fauna of the *Phacops* Beds is allied to that of the succeeding strata.

In addition to other fossils, the Ashgillian strata contain graptolites,

which have not been found, however, in the Ashgill Shales. *Dicellograptus anceps*, Nich., comes in the *Phacops* Beds, and ranges up into the beds above the Volcanic Group. The Ashgillian beds are, therefore, the zone of *Dicellograptus anceps*.

The succession in this district is much clearer than in the Lake District, and it is suggested that it be adopted as the type sequence for the Ashgillian beds of the North of England.

Some notes on the faunas of the Silurian rocks, of which the detailed sequence has been previously established, are given.

2. "The Trilobite Fauna of the Comley Breccia Bed (Shropshire)." By Edgar Sterling Cobbold, F.G.S.

The author describes a trilobitic fauna from the matrix of a breccia of Middle Cambrian age, found near Comley Brook, in one of the excavations made for the Excavations Committee of the British Association. This fauna includes forms referred to *Agraulos* cf. *quadrangularis*, Whitfield, *Conocoryphe æqualis*, Linnarsson, *C. bufo*, Hicks, *C. impressa*, Linnarsson, *Microdiscus punctatus*, Salter, together with new species of *Paradoxides*, *Dorypyge*, *Ptychoparia* (*Liostracus*), and some indeterminate forms, provisionally referred to *Agraulos* (*Strenuella*).

This breccia bed is made up of the recompacted waste of Lower Cambrian sandstones, many of the included blocks yielding species belonging to the *Protolenus Callavia* fauna. It rests directly upon bedded Lower Cambrian sandstone, and is therefore regarded as a basal deposit of the Middle Cambrian.

The fossils contained in the matrix indicate an horizon that is probably equivalent to a part of the *Paradoxides tessini* zone of Scandinavia. As they are specifically distinct from those of the Quarry Ridge Grits of Comley, which are also basal but rest upon Lower Cambrian limestones containing the *Protolenus Callavia* fauna, the inference is drawn that the two deposits are separated by a distinct interval of Cambrian time.

3. "Two Species of *Paradoxides* from Neve's Castle (Shropshire)." By Edgar Sterling Cobbold, F.G.S.

The author figures portions of two species of *Paradoxides*, collected in 1892 by Mr. J. Rhodes for H.M. Geological Survey. These are referred to *P. hicksi*, Salter, and to a new variety of *P. bohemicus*, Bœck.

Species of *Agnostus*, *Ptychoparia* (*Liostracus*), *Agraulos*, *Hyolithus*, and *Acrotreta* occur in the same rock-fragments, but are not sufficiently well-preserved for exact specific determination.

December 18, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communication was read:—

"On the Discovery of a Palæolithic Human Skull and Mandible in a Flint-bearing Gravel overlying the Wealden (Hastings Beds) at Piltdown, Fletching (Sussex)." By Charles Dawson, F.S.A., F.G.S., and Arthur Smith Woodward, LL.D., F.R.S., Sec.G.S.

The gravel in which the discovery was made occurs in a field near Piltdown Common, in the parish of Fletching (Sussex), and is

described by the first author. In the section exposed it is about 4 feet thick. It consists, for the greater part, of waterworn fragments of Wealden ironstone and sandstone, with occasional pebbles of chert, probably from the Greensand, and a considerable proportion of Chalk flints, which are also waterworn, all deeply stained with oxide of iron, and most of them tabular in shape. The human skull was originally found by workmen, broken up by them, and most of the pieces thrown away on the spot. As many fragments as possible were recovered by the authors, and half of a human mandible was also obtained by the first author from a patch of undisturbed gravel close to the place where the skull occurred. Two broken pieces of the molar of a Pliocene type of elephant and a much-rolled cusp of a molar of *Mastodon* were also found, besides teeth of *Hippopotamus*, *Castor*, and *Equus*, and a fragment of an antler of *Cervus elaphus*. Like the human skull and mandible, all these fossils are well mineralized with oxide of iron. Many of the waterworn iron-stained flints closely resemble the 'eoliths' from the North Downs near Ightham. Mingled with them were found a few Palæolithic implements of the characteristic Chellean type. The gravel at Piltdown rests upon a plateau 80 feet above the River Ouse, and at a distance of less than a mile to the north of the existing stream. It appears to cover several acres, but at the same level on the opposite (south) side of the river it is represented only by scattered flints. Numerous iron-stained tabular flints, like those of the Piltdown gravel, have been found in the basin of the Ouse between the Chalk escarpment and Sheffield Park and between this escarpment and Uckfield. As they are identical with the flints well known in the plateau deposits of the North and South Downs, it may be assumed that they have been derived from a plane formerly existing between those two points.

The human skull and mandible and the associated fossils are described by the second author. The skull (which unfortunately lacks the bones of the face) exhibits all the essential features of the genus *Homo*, with a brain capacity of not less than 1,070 c.c., but possibly a little more. It measures about 190 mm. in length from the glabella to the inion, by 150 mm. in width at the widest part of the parietal region; and the bones are remarkably thick, the average thickness of the frontals and parietals being 10 mm., while an exceptional thickness of 12 mm. is reached at one corner. The forehead is steeper than that of the Neanderthal type, with only a feeble brow-ridge; and the conformation of the occipital bone shows that the tentorium over the cerebellum is on the level of the external occipital protuberance, as in modern man. Seen from behind the skull is remarkably low and broad, and the mastoid processes are relatively small. The right mandibular ramus is nearly complete to the middle of the symphysis, lacking only the articular condyle and the upper part of the bone in advance of the molars. The horizontal ramus is slender, and so far as preserved resembles in shape that of a young chimpanzee (*Anthropopithecus niger*). The lower symphysial border is not thickened and rounded, as in man, but produced into a thin inwardly curved flange, as in the apes.

The ascending ramus is comparatively wide, with extensive insertions for the temporal and masseter muscles, and a very slight sigmoid notch above. Molars 1 and 2, which occur in their sockets, are typically human, though they are comparatively large and narrow, each bearing a fifth cusp. The socket of molar 3 indicates an equally large tooth, placed well within the ascending ramus of the jaw. The two molars have been worn perfectly flat by mastication, a circumstance suggesting that the canines resembled those of man in not projecting sensibly above the level of the other teeth. The weakness of the mandible, the slight prominence of the brow-ridges, the small backward extent of the origin of the temporal muscles, and the reduction of the mastoid processes, suggest that the specimen belongs to a female individual, and it may be regarded as representing a hitherto unknown genus and species, for which a new name is proposed.

The authors conclude that the Piltdown Gravel Bed is of the same age as the contained Chellean implements, which are not so much waterworn as most of the associated flints. The rolled fragments of molars of the Pliocene elephant and *Mastodon* are considered to have been derived with the flints from older gravels; while the other mammalian remains and the human skull and mandible, which cannot have been transported far by water, must be assigned to the period of the deposition of the gravel bed itself. The remoteness of that period is indicated by the subsequent deepening of the valley of the Ouse to the amount of 80 feet.

III.—Mineralogical Society.

Anniversary Meeting, November 12, 1912.—Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

Professor W. J. Lewis: Ilmenite from the Lengenbach Quarry. Embedded in the dolomite was found a minute crystal, irregular in habit, showing the forms 110, $10\bar{1}$, 100, 112, 111, 275. The best readings were obtained from pairs of faces of 101 and between them and faces of a prism, the corresponding angles being found to be 64° 47′ and 57° 33′ respectively.—Professor W. J. Lewis: Multiple Twin of Cassiterite. Threefold twinning is well and regularly developed on opposite sides of the crystal, which consists of two main portions with twin axes all in one plane, and the triplets so formed are connected together in a somewhat irregular way. Further, some of the individuals are twinned along pyramid faces inclined to the general plane so that the back of the crystal is unlike the front.—Arthur Russell: An account of the Minerals found in the Virtuous Lady Mine, near Tavistock. The following species were met with: chalybite, in pseudomorphs after fluor and barytes, termed respectively 'boxes' and 'slippers' by the miners; marcasite in sheaf-like aggregates; mispickel in two modifications; anatase, on one crystal of which was found a small crystal of brookite, the only one seen by the author from this locality.—Dr. A. Hutchinson: Some Graphical Methods in Crystallography and Crystal Optics. Diagrams of expressions involving sines, such as $\sin E = \beta \sin V$, are much simplified

by taking log sines for co-ordinates, the result being a series of parallel straight lines.—Dr. A. Hutchinson and W. Campbell Smith: Labradorite from St. John's Point, Co. Down. The large fresh crystals of felspar, which occur in a basaltic dyke, have physical characters—specific gravity 2·706, extinction on 010 and 001 $-23°$ and $-11°$ respectively, refractive indices α 1·5630, β 1·5665, γ 1·5712—which agree closely with the position of the felspar in the plagioclase series given by its chemical composition, which is approximately represented by the formula 33 Ab 5 Or 62 An.—Dr. G. F. H. Smith: Apparatus for preparing Thin Sections of Rocks. A description was given of the apparatus recently made for the Mineral Department of the British Museum.—Russell F. Gwinnell: Calcite Crystals from a Water Tank. The crystals, which were deposited during the dry summer of 1911 from water derived from a spring in the marlstone of Belton Park, near Grantham, Lincolnshire, averaged 0·1 mm. in greatest diameter, and showed the unusual unit rhombohedron form $10\bar{1}1$.

CORRESPONDENCE.

BEMBRIDGE LIMESTONE AT CREECHBARROW HILL.[1]

Sir,—As Mr. Keeping's latest Report on Creechbarrow Hill leaves the question of its true geological structure still somewhat uncertain, I venture to draw attention to one or two points which may, perhaps, be of some help towards arriving at a correct conclusion.

1. If the Pipeclay is to be relied upon as a datum-line, some idea can be formed of the approximate thickness of strata between it and the Limestone above.

2. Latest borings on the eastern flank have proved Pipeclay as high up as 393 feet O.D., at a horizontal distance below the summit of not more than 610 feet. Shown thus—

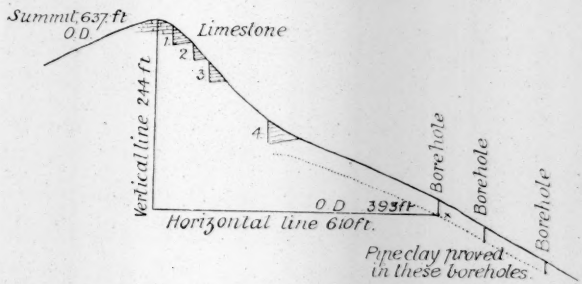


Diagram of Creechbarrow Hill, showing excavations and boreholes.

1, 2, 3, 4. Trenches which showed stratified deposits of gravel, large flints, sand, and clay, apparently dipping into the hill.

N.B. Most probably the outcrop of the Pipeclay is much higher up, leaving so much less space for later deposits.

[1] See British Association Report, Section C (Geology), Dundee Meeting, September, 1912, on Mr. Keeping's further examination of Creechbarrow Hill, Isle of Purbeck. (GEOL. MAG., November, 1912, pp. 509–10.)

3. There is a proved thickness of 166 feet of Bagshot Beds above the Pipeclay Series at Worgret Well, some 3¾ miles away N.N.W. (See Proc. Dorset Field Club, vol. xxvii, p. 162.)

4. A 10 or 20 feet contoured plan on a fairly large scale, indicating where trenches and borings have been made and their sections already described, would be a useful aid to any keen geologist who may be interested enough to make further investigation.

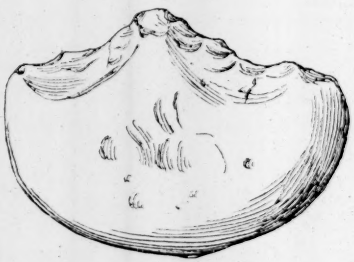
A. H. Bloomfield
(Twenty-five years Collector to the late Mr. W. H. Hudleston).

Grange Road, Wareham.
November 8, 1912.

FLINT IMPLEMENTS OF EARLY MAN: GEOLOGISTS' ASSOCIATION.

Sir,—Among the exhibits at the conversazione of the Geologists' Association held on Friday, November 1, at University College, London, was one by Mr. Hazzledine Warren, F.G.S., illustrating pressure-flaking upon flints produced experimentally.

Mr. Warren had adopted the method of fixing together with some cementing material two stones with the obvious intention of conveying the impression that in each case the stones so joined were the only two which had been used in producing the flaking upon the uppermost one. When, however, I examined one of the exhibits which showed the uppermost stone with two pressure 'bays', it was at once clear to me that these two hollows could, under no



Eolith from Plateau Gravel, Ightham. (Prestwich Collection.)

possible circumstances, have been produced by pressing it upon the underlying stone. On questioning Mr. Warren I elicited the information that he was unable to recollect whether the underlying flint *was* the one upon which the other had been flaked, and, after a long experience of flaking flints by pressure, I have confidence in stating that two such hollows as were shown could not be produced by pressing on any *single* stone of any sort or kind. As this question of the natural fracture of flint is of the utmost importance in deciding as to the 'humanity' or human origin or otherwise of certain ancient flaked stones, it appears to me most regrettable that Mr. Warren was not more careful in exhibiting reliable specimens. As also some

of those present at the conversazione who did not closely examine Mr. Warren's specimens may have gone away with an erroneous idea of the flaking which can be produced by pressing one stone upon another, it seems desirable that this matter should be made public and all misunderstanding about it removed.

J. Reid Moir.

12 St. Edmund's Road,
Ipswich.

HOME-MADE NATURAL EOLITHS, 'THE WARRENS.'

Sir,—At the London Geologists' Association Soirée, November 1, 1912, there was a most interesting display of the 'Warrens' as made by Mr. Hazzledine Warren, F.G.S. Mr. Warren's method seems to me a fallacious way to prove a natural origin for the Eolithic 'Cupid's bow' type, such as he showed on Friday night. Surely the proof, if any, is that they are 'Warrens' and nothing more. For, first, Mr. Warren selects a form of Eolith he deems as quite a natural one, the 'Cupid bow', and then sets to work to see how best he can produce this by a machine he has made. Second, he selects a suitable piece of flint and, further, two equal-sized pebbles, places them securely in position, and applies and so controls the pressure as to produce the best results to him. It seems to me quite impossible to compare any procedure of nature with all this carefully thought out and carefully controlled mechanical one. Nature, too, shows all her productions, and such as he might deem her successes and failures. Surely to be fair Mr. Warren should do the same. He, too, must be more successful now than he was. Let him, then, so improve his methods and his machine and make, say, palæoliths and neoliths. Would not this prove that nature made *these*? Mr. Reid Moir's show was the opposite, as he produced his home-made rostro-carinate forms, but sought to prove that *man* made those. Surely this seems far more logical. I see now that as photographs have been taken under water showing the hooked trout fighting with the angler, we may yet hope to see such taken under the sea, showing how water-driven stones really do their work upon each other. In the absence of any facts mere speculation seems useless.

F. J. Bennett.

Acacias, West Malling.
November 13, 1912.

OBITUARY.

RAMSAY H. TRAQUAIR, M.D., LL.D., F.R.S. L. & E., F.G.S.

Born July 30, 1840. Died November 22, 1912.

It is with deep regret we record the death of our old and valued friend and fellow-worker in palæontology for so many years, Dr. R. H. Traquair, lately Keeper of the Natural History Collections

in the Museum of Science and Art,[1] Edinburgh, which occurred on November 22, 1912, at his residence, "The Bush," Colinton, Midlothian, in his 72nd year.

Early in life he took a keen interest in fossil fishes, his attention having been arrested by discovering a portion of a Palæoniscid fish in the Wardie Shales. In passing his medical course in the University of Edinburgh, where he studied under Professor Goodsir and Sir William Turner, he chose as the subject for his medical thesis the asymmetry of the flat fishes, for which he was awarded a gold medal.

In 1866 Traquair became Professor of Natural History in the Royal Agricultural College, Cirencester; in 1867 Professor of Zoology in the Royal College of Science, Dublin; and in 1873 Keeper of the Natural History Collections in the Science and Art Museum, Edinburgh, a post which he held till his retirement in 1906.

At the Edinburgh Museum he had the charge of the collection of fossil fishes, and during thirty-three years he acquired a very fine series of fish-remains from the Old Red Sandstone and Carboniferous rocks of Scotland.

His researches led to the entire revision of the classification and nomenclature of Agassiz and other early investigators, especially in the Palæoniscidæ and the Platysomidæ, Traquair's work being based on the morphological structure, not on the mere outline of the body or the configuration of the scales and teeth.

During his long career Dr. Traquair published upwards of 130 papers on zoological and palæontological subjects, chiefly on fossil fishes, which have mostly appeared in the volumes of the Palæontographical Society, the Transactions of the Royal Society of Edinburgh, and the Royal Physical Society. Between 1871 and 1902 he also contributed about 30 papers to the Geological Magazine. By means of the fish-remains he arranged the Carboniferous rocks of Scotland in two divisions, and on the same principle he established a triple classification of the Lower, Middle, and Upper Old Red Sandstone.

For several years he filled the office of Swiney Lecturer on Geology at the British Museum (Natural History), where he displayed his remarkable talent as a draughtsman on the blackboard. Much of his success in Ichthyology no doubt was the result of this graphic skill and accurate anatomical knowledge in drawing fossil fishes.

He was the recipient of many honours in recognition of his work. In 1881 he was elected an F.R.S. of London; the Lyell Medal was awarded him by the Geological Society in 1901, and a Royal Medal in 1907 by the Royal Society. His life and portrait appeared in the June Number of the Geological Magazine for 1909 (pp. 241–50).

He was quite lately engaged on his final memoir on the Palæoniscidæ for the Palæontographical Society, and up to the very last of his life, even when his health had given way, he bravely continued his labours until the end.

His widow, two sons, and one daughter survive him.[2]

[1] Now known as the Royal Scottish Museum.

[2] In part from the *Scotsman*, November 23, 1912.